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The crystal structure of Shortite, $\text{Ca}_2\text{Na}_2(\text{CO}_3)_3$

By FRANS E. WICKMAN

With 2 figures in the text

Previous investigations. Shortite from Sweetwater County, Wyoming was described by J. J. FAHEY (1939). W. E. RICHMOND (1941, 1941 a) studied its X-ray crystallography and found the space-group to be $C_{2v}^{14}-Amm$.

Material. A small clear crystal showing $c\{00\bar{1}\}$, $a\{100\}$, and $e\{011\}$ obtained from the original locality was used for the present investigation. The crystal was cut in order to obtain a more equi-dimensional size around the a -axis (diameter 0.3 mm).

Unit cell and space-group. Equi-inclination Weissenberg photographs were taken around the a -axis using filtered copper radiation. The cell dimensions found were within the limits of error equal to those found by RICHMOND: $a = 4.98 \text{ \AA}$, $b = 10.97 \text{ \AA}$, $c = 7.10 \text{ \AA}$. The cell contains two molecules $\text{Ca}_2\text{Na}_2(\text{CO}_3)_3$. The space-group determined by RICHMOND, $C_{2v}^{14}-Amm$ was accepted.

Atomic positions. It is natural to assume the existence of CO_3 -groups in the structure. In all carbonates so far investigated, the CO_3 -group forms an equilateral triangle with the carbon atom at the centre and the three oxygen atoms at the corners. According to the well-known investigation by N. ELLIOTT (1937) the distance C—O in calcite is $1.31 \pm 0.01 \text{ \AA}$, and this value has been used in the present investigation.

An indication of the orientation of the CO_3 -groups may be found from the optical properties. FAHEY determined the indices of refraction to be $n_\alpha(c) = 1.531$, $n_\beta(a) = 1.555$, $n_\gamma(b) = 1.570$. Using the well-known theory of W. L. BRAGG (1924) of the optical properties of crystals, a rough calculation shows that the trigonal axis of four carbonate groups probably must be parallel to the bc -plane and that the axis of two must be parallel to the a -axis. (For a more complete discussion of the optical properties see p. 98). The atomic positions and symmetry elements of the space group are (according to I. T. 1933):

$$\begin{aligned} &C_{2v}^{14}-Amm \quad (000; 0\frac{1}{2}\frac{1}{2}) + \\ &2: (a) 00z \quad (b) \frac{1}{2}0z \\ &4: (c) x0z \quad \bar{x}0z \quad (d) 0yz; 0\bar{y}z \quad (e) \frac{1}{2}yz; \frac{1}{2}\bar{y}z \\ &8: (f) xyz; \bar{x}\bar{y}z; \bar{x}yz; x\bar{y}z \end{aligned}$$

Point symmetry:

$$\begin{aligned} &mm \text{ in } (a), (b) \\ &m \text{ in } (c), (d), (e) \\ &I \text{ in } (f) \end{aligned}$$

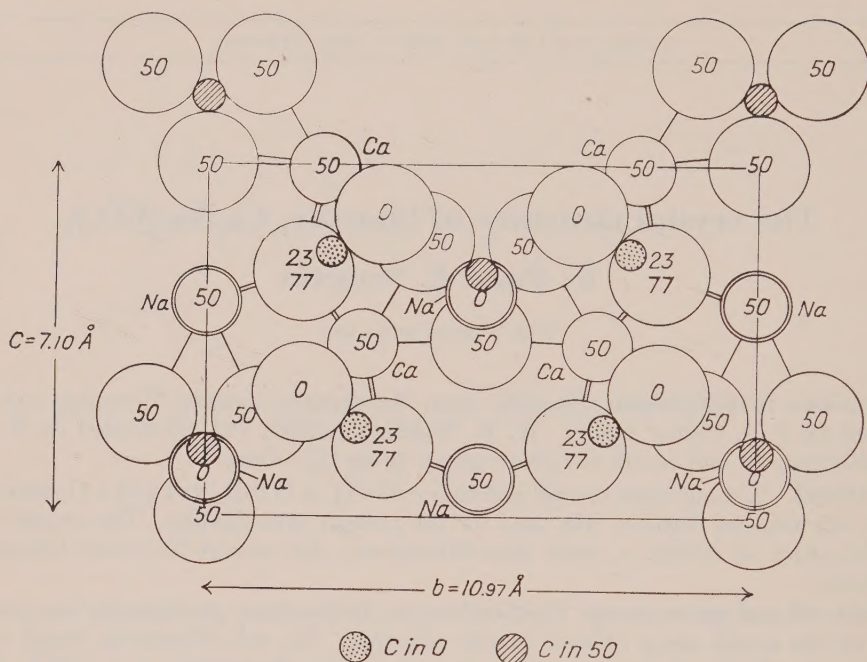


Fig. 1. The structure of shortite projected on (100).

So it is probable that two carbonate groups occupy the positions 2 (a) or 2 (b). On account of the point symmetry of these atomic positions their orientation is fixed. It is apparent that this space group has no centre of symmetry, so we arbitrarily fix the positions of the two CO_3 -groups at the following values of the atomic positions and parameters which we can easily calculate from the dimensions of the CO_3 -group. 2 O in (b) $z = 0.000$, 2 C in (b) $z = 0.185$ and 4 O in (e) $y = 0.104$, $z = 0.276$.

Now space considerations and reflections of the types $(0k0)$ and $(00l)$ were used to determine approximately the parameters of the other atoms. The final values of the parameters obtained from all the reflections $(0kl)$ are:

2 Na I	in (a)	$z = 0.130$
2 Na II	in (b)	$z = 0.600$
4 Ca	in (e)	$y = 0.213, z = -0.014$
4 C I	in (d)	$y = 0.226, z = 0.743$
2 C II	in (b)	$z = 0.185$
4 O I	in (d)	$y = 0.325, z = 0.850$
8 O II	in (f)	$x = 0.230, y = 0.177, z = 0.690$
2 O III	in (b)	$z = 0.000$
4 O IV	in (e)	$y = 0.104, z = 0.276$

A comparison of the observed and calculated intensities is given in Tables I and II.

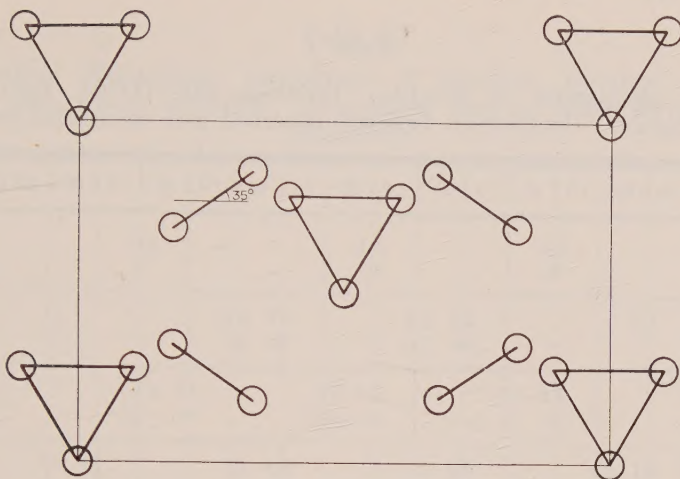


Fig. 2. The arrangement of the CO_3 -groups in the shortite structure, projected on (100).

No correction was made for the rotation factor in Table II. The agreement between calculated and observed intensities must be regarded as satisfactory.

Discussion of the structure. The structure of shortite is shown projected on (100) in Fig. 1. The arrangement of the CO_3 -groups is shown schematically in Fig. 2. The spatial arrangement of the oxygen atoms around the sodium and calcium atoms is rather irregular. The interatomic distances are:

	Number of atoms	Kind of atoms	Distance
Na I	2, 4	O I, O II	2.48, 3.86
	2, 4	O III, O IV	2.66, 2.92
	2	C II	2.52
		Na II	4.16
		Ca	3.56
Na II	4, 4	O I, O II	3.61, 2.44
	2, 1	O III, O IV	2.84, 2.56
	2	C II	2.94
		Ca	3.89
Ca	2, 2	O I, O II	2.94, 2.32
	2, 1	O II, O III	2.52, 2.34
	1, 1	O IV, O IV	2.38, 2.50
	1	C I	3.04
C I	1, 2	O I, O II	1.31, 1.32
C II	1, 2	O III, O IV	1.31, 1.31
O I		O IV	2.66
O II		O III, O IV	3.24, 3.33

Assuming a co-ordination number of eight for Na I, seven for Na II, and nine for calcium, we find that PAULING's rule is well satisfied: O I 2.03, O II 1.92, O III and O IV 2.17.

Table I

Weissenberg photograph of Shortite. Rotation axis $[100]$. Zero layer line. Cu- K_α -radiation. Comparison between observed and calculated intensities.

	0 k 0	0 k 1	0 k 2	0 k 3	0 k 4	0 k 5	0 k 6	0 k 7	0 k 8
0.13. <i>l.</i>		2.5 m.		1.4 m.					
0.12. <i>l.</i>	1.2 —		24 m.		37 m.				
0.11. <i>l.</i>		7.0 w.		0.1 w.		12 m.			
0.10. <i>l.</i>	37 st.		5.3 m.		3.1 w.		23 m.		
0.9. <i>l.</i>		24 m.		5.3 st.		24 st.		60 m.	
0.8. <i>l.</i>	0.0 v.w.		4.5 —		4.0 —		14 w.		
0.7. <i>l.</i>		23 st.		17 m.		4.3 m.		10 m.	
0.6. <i>l.</i>	70 st.		24 m. +		19 m.		6.8 m.		8.8 w.
0.5. <i>l.</i>		71 v.st.		61 st.		28 st.		12 v.v.w.	
0.4. <i>l.</i>	51 st.		110 v.st.		2.3 —		5.4 v.w.		24 m.
0.3. <i>l.</i>		38 st.		162 v.st.		3.4 w.		9.4 st.	
0.2. <i>l.</i>	260 v.st.		51 st.		65 st.		13 m. +		8.5 m.
0.1. <i>l.</i>		21 st.		55 st.		2.3 v.v.w.		6.8 v.w.	
0.0. <i>l.</i>			42 st. +		37 st.		20 w.		23 w. +

v.st. = very strong. st. = strong. m. = medium.

An approximate calculation of the refractive indices of shortite from the atomic arrangement. W. L. BRAGG (1924) has proposed a very interesting method of calculating the refractive indices of crystals. His method is thoroughly discussed in his

Table II^c

Equi-inclination Weissenberg photograph of Shortite. Rotation axis $[1\ 0\ 0]$. First layer line. Cu-K $_{\alpha}$ -radiation. Comparison between observed and calculated intensities.

	1 k 0	1 k 1	1 k 2	1 k 3	1 k 4	1 k 5	1 k 6	1 k 7	1 k 8
1.13. l.		0.2 —							
1.12. l.	11 w.		9.6 w.		9.4 st.				
1.11. l.		5.8 m. +		3.3 v.w.		4.7 w.			
1.10. l.	17 w.		3.5 —		13 m. —		9.4 m.		
1.9. l.		3.3 w.		37 m.		18 m.			
1.8. l.	1.9 w. —		1.3 m. —		2.1 v.w.		1.5 —		
1.7. l.		39 st.		6.8 m.		0.4 m.			
1.6. l.	7.5 w. —		6.9 w.		1.1 v.w.		3.1 v.w.		
1.5. l.		73 m.		31 w.		41 st.			
1.4. l.	25 m.		78 st.		3.2 w.		8.6 w.		14 st.
1.3. l.		131 st.		0.9 w.		0.2 m.		19 m. —	
1.2. l.	13.4 m.		86 st.		17 st.		16 m.		5.8 m.
1.1. l.		5.6 m.		72 m. +		14 m.		2.4 w.	
1.0. l.			170 st.		80 st.		13 m.		4.8 st. —

w. = weak.

v.w. = very weak.

v.v.w. = extremely weak.

original paper and in a paper by W. H. ZACHARIASEN (1933). In the present case the use of BRAGG's method would involve laborious numerical calculations, and so we shall only use a rough approximation. From Fig. 2 it may be seen that we have

two kinds of CO_3 -groups. The first one is parallel to the (100) plane and the second one parallel to the a -axis, making an angle of 35 degrees with the (001) plane.

We can use the well-known expression for the molecular refractivity of a compound

$$\frac{M}{d} \cdot \frac{n^2 - 1}{n^2 + 2} = \sum a_v I_v$$

where M is the molecular weight, d the density, n the refractive index, a_v the number of atoms v in the "molecule", and I_v the ionic refractivity of the atom.

The ionic refractivities are according to J. A. WASASTJERNA (1923): Na^+ 0.74, Ca^{2+} 1.99, and carbon negligible. According to BRAGG the ionic refractivity of oxygen may be taken as 3.30. He has shown that the CO_3 -group is strongly anisotropic under the influence of an electric field and is to the first approximation responsible for the high birefringence of many carbonates.

By only taking the interaction of the oxygen atoms in the same CO_3 -group into consideration, BRAGG found (p. 378-79) that the ionic refractivity in the direction of the trigonal axis of the group was 0.815 of the normal value, whereas parallel to the plane of the group it was 1.17 times the normal value.

In the case of shortite we have the problem that a field parallel to the b - or c -axis makes an angle of 35° with the group. Therefore we shall make the rather plausible assumption that the values of the ionic refractivities for directions differing from those given above can be calculated from a rotation ellipsoid with the axis 0.815 and 1.17. In the direction of the b -axis we find 1.02 and in the direction of the c -axis 0.90. Using these values, and $d = 2.63$ we obtain the values tabulated in Table III. The agreement between the observed and calculated indices of refraction is good, bearing in mind the crude approximations involved in the calculations.

Table III

Observed (Fahey)		Calculated	
n	Orientation	n	Orientation
1.531	c	1.515	c
1.555	a	1.545	a
1.570	b	1.555	b


Acknowledgement. This investigation was started at the Department of Geology, University of Chicago. The material was obtained from the University of Wyoming through the courtesy of Dr A. HAGNER; Dr J. FISHER furnished much help and advice with the preparation of the photographs.

Swedish Museum of Natural History, Department of Mineralogy.

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Calcareous freshwater sediments from northern Bohuslän

By IVAR HESSLAND

With 4 plates and 3 figures in the text

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Introduction

The Quaternary marine shell deposits of northern Bohuslän are well known both to zoologists and geologists since long ago. They have been investigated on several occasions, and have often been discussed in connection with questions of Quaternary geology. The shell-bearing freshwater deposits of this district, on the contrary, have attracted only little attention in spite of the fact that they are not very rare.¹

¹ ANDERSSON (1893, p. 35) and SANDEGREN (SANDEGREN-JOHANSSON 1931, p. 119) mention two shell-bearing calcareous freshwater deposits from southern Bohuslän. Some few molluscs

The shells occur in calcareous sediments. Some of the deposits were observed at the peat soil investigation performed by the Geological Survey of Sweden (v. POST 1923). At least 6 calcareous freshwater deposits in northern Bohuslän became known as a result of this investigation (LUNDQVIST 1925, Fig. 31). In the years 1937–1939 I had the opportunity of examining 11 deposits in this part of the province. Eight of them are situated in the parish of Kville, 2 in Tanum, and 1 in Skee (Fig. 1). They are situated within the range of 65–118 m above the sea. They were accumulated during the later part of the Finiglacial period and the first part of the Postglacial; one of the deposits is somewhat older than the bulk (entirely Finiglacial) and one somewhat younger (most probably referable to the later half of the Ancyclus period).

The method employed in the examination of peat soils by the Geological Survey (linear registration of peat soils >5 hectares; the researches limited to areas situated within a distance of 5 km from the nearest railway, harbour, or waterway) does not permit a complete knowledge of the frequency of the calcareous freshwater sediments of the district. As my investigation is also not complete, it is accordingly rather probable that more such deposits occur there.

The chief aim of my investigation was to study the occurrence of subfossil molluscs in northern Bohuslän. In addition, the research came to include some other groups of animals, especially ostracods, which, next to molluscs, are the most abundant in these deposits in species as well as in individuals. No other group is so numerously represented by far as molluscs and ostracods. Now and then, however, eggs and cocoons of *Turbellaria rhabdocoela*, cocoons of *Oligochaeta*, ephippia of *Daphnia*, statoblasts of Bryozoa, fragments of chitin from Insecta, and fishbones may be found.

In order to obtain an idea of the vegetation of the ancient ponds, I have also noted the occurrence of certain plant remains, viz. seeds of phanerogams and oospores of Charophytes. Like the animal fossils, the plants are certainly autogene. In many respects it is important to have a knowledge of the higher vegetation of the ponds, on which a great many animal organisms, not least molluscs, but also ostracods and others depend. (Again, the vegetation must be influenced by several elements produced by the vital processes of these organisms, such as carbon dioxide, phosphorus, nitrogen, and other excretory products.) Additionally, the higher vegetation is not without importance to the precipitation of calcium carbonate in lowering the CO₂-pressure which causes calcium bicarbonate to be transformed into neutral carbonate.

The percentage of phytogene substances in the fraction < 1/2 mm was established in order to obtain an idea of the nourishment in the water of the ancient ponds. These substances include not only detritus from the macro-vegetation but also remnants of the micro-vegetation. A more detailed examination of the phytogene particles was not made, however.

Two further components of this fraction were analysed, viz. the percentages of calcium carbonate and minerogene particles, both of which have influenced the development of the ancient fauna and flora.

Lack of resources has rendered it impossible to analyse important chemical el-

— were found. ANDERSSON referred his locality to the so-called oak period. Judging from a pollen diagram (SANDEGREN-JOHANSSON 1931, Fig. 43) the shell-bearing section of the second deposit is referable to the earliest part of the Postglacial period (the A⁰ in the upper part, the C⁰ in the lower, the BM obviously somewhere below).

elements in the stratal sequences, such as phosphorus, sulphur, potassium, and nitrogen. Curves of the distribution of these elements in similar sediments are presented in MUNTHER—HEDE—V. POST 1925 A (Fig. 69).

The material was collected in the years 1937–1939. The laboratory investigation of one locality (Kålstad) was made in 1937 but was completed at the examination of the remaining localities in 1944.

The pollen analyses were performed in 1947 and 1948, hence the results of the investigation could only be published now.

Origin of the calcium carbonate

It may seem remarkable that calcareous freshwater sediments are relatively so frequent in such an area as the one now considered where the bed-rock practically exclusively consists of granite and gneiss. As appears from a map showing the occurrence of calcareous freshwater sediments in Sweden (LUNDQVIST 1940, p. 11), these are situated for the most part within areas with calcareous rocks or calcareous glacial deposits. From another map (LUNDQVIST 1925, p. 117) it appears that the southern part of the district investigated consists of »less calcareous» soils. In the northern part of the district the soils are indicated as non-calcareous.

The calcium carbonate might be expected to be derived from calcareous glacial deposits transported from the Cambro-Silurian region of south-eastern Norway. The ancient date of the calcareous freshwater sediments might indicate that they were formed by the leaching of such deposits. This process should thus have begun rather soon after the elevation of the land above the sea level, and the calcium carbonate should have been used up at such an early date that there was nothing left for formation of calcareous freshwater sediments during the later part of the Postglacial period.

However, the calcium carbonate of the calcareous freshwater deposits of northern Bohuslän does not seem to be of this origin, except possibly to a small extent. Fig. 1 shows the position of the deposits in relation to the Cambro-Silurian region of south-eastern Norway. The direction of the glacial striae in the southern part of the area investigated — the district covered by the geological map Fjällbacka — indicates that the main part of the glacial deposits originate from areas devoid of calcareous rocks. However, a few NNW–SSE striae give some slight support to the alternative that calcareous boulders have been transported by the Ice from Norway. According to DE GEER (1902, p. 32), the striae in the outer islands of the northern part of the area — the district covered by the geological map Strömstad — have a "tendency to the south" in comparison with the striae in the inner part of the district, a tendency, which "is apparently influenced by the Ice which forced its way out from the valley of the Kristianiafjord". The direction of the striae in the Islands of Koster is "N 35° E with deviation from 5 to 10° to each side". DE GEER is of the opinion that drift boulders from the Oslo region have been transported here exclusively by icebergs (op. cit., p. 57). How the transportation of calcareous boulders to northern Bohuslän has taken place is, however, questionable, but a definite answer to this problem is of no decisive importance here. Let us instead examine the distribution of the Cambro-Silurian drift boulders in this area. They increase northwards and towards the coast. There is also an increase northwards of



Fig. 1. Map showing the position of the N. Bohuslän calcareous freshwater deposits investigated here (black dots). Black areas = the Cambro-Silurian of SE. Norway. Direction and frequency of ice striae indicated graphically (compiled from DE GEER 1902).

essexite and other igneous rocks of the Oslo region.¹ However, those parts of northern Bohuslän where the frequency of calcareous boulders is greatest, i. e., in the north and the west, are very poor in calcareous freshwater deposits. Such deposits are, on the contrary, fairly common in the south-eastern part of the district, where the frequency of calcareous boulders is least. The reason for that might be suggested to be that the calcareous boulders in the latter area have been dissolved and the calcium carbonate transformed into calcareous freshwater sediments. An objection against this is that the leaching of the calcareous boulders in the northern part of the district should have resulted in the production of still more calcareous freshwater sediments. That processes of leaching really have taken place there, may be seen from the fact that originally calcareous Gotlandian limestone boulders have been leached out in such a degree that only a porous minerogene mud-stone remains. However, calcareous freshwater sediments are rare within this area.

On the other hand, Cretaceous boulders might be expected to be the source of the freshwater calcium carbonate. Danian chalk attached to flint boulders, and boulders of so-called Saltholm limestone can be found rather often along the coast (also cf. WIMAN 1912). The frequency of such calcareous boulders decreases towards the north and in all directions away from the shore. This fact and also their scarcity, exclude the idea that they should be the parent substance of the freshwater calcium carbonate.

On account of its scarcity it may be denied that calcite in fissures (LJUNGNER 1927) should constitute the parent substance.

The freshwater calcium carbonate is certainly derived from Quaternary shell-bearing marine deposits. As a matter of fact, all the calcareous freshwater deposits examined are situated close to such layers. They are generally underlain by shell-bearing marine clays with a high percentage of calcium carbonate, and shell beds are often situated in their immediate vicinity. The number of shell beds in the southern part of the district (the Kville parish) where the calcareous freshwater deposits are more numerous than elsewhere in the district is very great; marine clay sediments rich in shells are also very common (cf. the above-mentioned maps by LUNDQVIST). Additionally, the shell beds are often of large size, as for instance that at Hjelpedsten. In certain cases, such as at Kålstad, parts of the shore of the ancient pond were identical with the former shell-bearing sea shore.

The idea that the calcium carbonate of the freshwater layers is derived from Quaternary shell-bearing deposits is supported by the fact that shells of small marine species, especially Ostracoda and Foraminifera (chiefly *Elphidium* spp.), and also fragments of larger marine shells (especially *Mytilus edulis* L.) are embedded in the freshwater layers, above all in their bottom parts. The locality Klingseröd I is an example of this. *Balanus* shell plates occur there in the three bottommost samples, and fragments of *Mytilus* and shells of *Elphidium*, these being more mobile, in the seven bottommost samples.

As just mentioned, the calcareous freshwater sediments in northern Bohuslän are referable to the later part of the Finiglacial period and/or the first part of the Postglacial. No later calcareous freshwater sediments have been observed there,

¹ As a matter of fact, rhombporphyry boulders are rather common in the whole of the coastal region. These blocks are of local origin to a large extent, originating from the well-known rhombporphyry dike which begins in the Oslo area and continues southwards through the whole coastal zone of northern Bohuslän. Essexite and allied rocks, however, do not occur in the dike; accordingly such boulders must originate from the Oslo region where they are common.

nor has any recent precipitation of calcium carbonate in lakes or ponds been noticed. In several cases non-calcareous freshwater sediments are being formed close to marine shell beds.

It is difficult to trace the reason for this phenomenon. Within other Swedish provinces LUNDQVIST has observed that the process of leaching of calcium carbonate is apparently confined to certain periods (1925, p. 114). The leaching process ceased as the stores of calcium carbonate were emptied. However, LUNDQVIST states (1940, p. 16) that precipitation of calcium carbonate has ceased also in areas with calcareous rocks, and, further, that the sediment in certain lakes is non-calcareous in spite of the fact that the water is highly calcareous. He adds that the reason for these remarkable circumstances is not known. The failing precipitation of calcium carbonate may, however, be due to the fact that soil acidity has increased as a consequence of an increased production of humus substances. In Gotland lakes there is a narrow non-calcareous sedimentary zone just off the shore where it consists of peat (LUNDQVIST 1940, p. 14). This is considered by LUNDQVIST to be caused by humus acids.

Material and methods

Heights of the localities above the sea were measured with an aneroid barometer (PAULIN system).

When possible, the material used for examination was taken from the walls of a pit, dug through the sequence of strata. Samples were also taken by the use of a can-auger.

The material preserved in dry state was dispersed by means of dilute peroxide of hydrogen before the laboratory examination. Particles < 0.5 mm were detached. This fraction, hardly containing any shells or fruits, was not analysed with regard to these components.

The percentage of calcium carbonate was ascertained by treatment with dilute hydrochloric acid. The content of plant substances was established by boiling in peroxide of hydrogen (15–20 per cent) during a period of 3–4 hours.

In those cases when sediment pillars through the whole shell-bearing layers were parted and examined quantitatively, the data of frequency have been illustrated graphically by distribution curves. These are constructed on the basis of histograms, made in accordance with current methods. As known, the principle of histograms is based on the fact that frequency is represented by surface units.

The datings are based on pollen analyses.

Notes on the pollen diagrams

The pollen analyses were only made in order to date the shell-bearing freshwater layers. The diagrams will not be discussed here from a special pollen-analytical point of view. This would be to precede such a far-reaching discussion by Dr. M. FRIES who is elaborating a comprehensive series of diagrams from middle Bohuslän and adjacent parts of Dalsland. In this connection, only the leading principles of dating followed here are briefly commented on and some notes on the vegetation are made.

v. POST (1947 A), in his extensive N. Halland investigation, attached great importance to some pollen-statistically characterized levels, especially the A^0 ("the

beginning of the rising *Alnus* curve”), the C^0 (“the beginning of the rising hazel curve”), and the BM (“a great and distinct *Betula* maximum, the frequency generally exceeding 80%”). They appear in the sequence $BM-C^0-A^0$.

The BM was developed 100–200 years before the year 0 acc. to DE GEER’s time scale (v. Post 1947 A, p. 210), thus about 6800–7000 B. C.

The A^0 is referable to about 6300 B. C. (cf. FLORIN 1944, Pl. IX).

In the present diagrams the *Betula* curve, as a rule, forms two maxima; in the locality Flöghult which is situated more to the north than the majority of the localities only one maximum is developed which certainly corresponds to the BM acc. to v. Post.

The upper maximum generally appears somewhat below the C^0 but it may also be practically simultaneous with the C^0 . The *Betula* and *Pinus* curves cross each other or approach very closely just above the upper *Betula* maximum. The two maxima are separated by a distinct and fairly broad and regular concavity in the *Betula* curve. The lowest point of this concavity falls 30–40% lower than the maxima, and the *Pinus* and *Betula* curves are closely approached or cross each other at that level. The upper maximum can be practically equal to the lower one (cf. Askeröd, Klingseröd II, and Rabbalshede) but it can also be smaller (Klingseröd I and Kålstad). At Klingseröd I, Klingseröd II, and Askeröd which are situated about 100, 97 and 99 m resp. above the sea the lower maximum appears just at the marino-limnic boundary, or a few centimetres below this level. At Kålstad and Rabbalshede which are situated about 89 and 94 m resp. above the sea the lower maximum appears somewhat deeper (35 and 45 cm resp. below the marino-limnic boundary).

The great lower maximum at Klingseröd I (level 501) seems to be that which corresponds most closely to the BM . It is even more difficult to judge whether this applies to the lower maximum of the other localities. However, the positions of the maxima in the stratal sequences of the above-mentioned localities in relation to the heights above the sea of the respective marino-limnic boundaries support the idea that, in fact, it might be taken for the BM . The datings here are made in accordance with that; however, the distinction is of little practical importance, the age difference being small (cf. diagram p. 111). It is hoped that the significance of the maxima will be considered at further investigations by other students. At any rate, they seem to be synchronous levels (though the upper perhaps only of local importance). The upper maximum is here called BM^{sup} . and the lower BM^{inf} .

As seen in the Flöghult profile a distinct *Pinus* maximum appears somewhat below the BM . It may correspond to v. Post’s Pm^1 , as also held by him in a discussion; according to v. Post the Pm^1 was developed at the Y IV stage of the Baltic corresponding to the development of, inter alia, the Brattforshed in eastern Värmland.

Concerning the *Alnus* curve, this one generally begins with low values before the great rise.

Corylus forms a distinct Boreal maximum in several localities (Kålstad, Stuvängen, Branstaby, and Hjelpedsten), but in the other localities the maximum is low or scarcely discernible. These latter localities are situated somewhat more eastwards; also in the northern Flöghult profile the Boreal hazel frequency is low.

The continuous mixed oak wood curve begins above the A^0 for the most part, but it also begins fairly often contemporaneously or somewhat below.

The beginning of the continuous *Tilia* curve was ascertainable in several localities.

It generally appears at about the great rise of the *Alnus* curve or somewhat later. The T^0 is referable to about 5100–5000 B. C. in eastern Middle Sweden acc. to FLORIN (1944; Pl. IX). There is some uncertainty with the dating of the T^0 on the Swedish west coast, however, as communicated verbally by Prof. v. Post.

Pollen grains of mixed oak wood trees as well as of *Alnus* and *Corylus* appear, partly rather abundantly, below the $BM^{inf.}$, even in sediments deposited just off the retiring Ice border (HESSLAND 1949). These grains are obviously xenogene.

A few notes may be made cursorily as regards the occurrence of some other types of pollen.

Hippophaë occurs in all localities, partly abundantly (Flöghult maximally 20% of the AP pollen). The highest frequency most often appears somewhat above the marino-limnic boundary, but the frequency may also be high just below this boundary. The species generally seems to have disappeared before the A^0 ; in two localities, however (Rabbalshede and Fossane), scattered pollen grains were found even around the T^0 .

Contemporaneously with the appearance of *Picea* the Ericacean pollen frequency was greatly increased, as observed at Flöghult; a so-called recurrency surface was developed at the same time.

Pollen grains of terrestrial herbs occur in generally rather small numbers. They are referable to Compositae, Ranunculaceae, Rosaceae, Caryophyllaceae, Umbelliferae, Chenopodiaceae, and Polygonaceae. Pollen grains of the following genera were observed: *Plantago*, *Artemisia*, *Rubus*, *Drosera* (Flöghult, 797–803), *Epilobium* (cf. *angustifolium*), *Rumex* (cf. *acetocella*), *Galium*, and possibly *Helianthemum* (Klingse-röd I, 556).

The frequency of *Artemisia* which is considered a characteristic component of the open soil vegetation appearing just after the retreat of the Ice has been reproduced separately in the diagrams. It sometimes occurs rather abundantly before the $BM^{inf.}$ but appears only sporadically thereafter. It disappears or has a low frequency during the *Betula maxima*.

Concerning the remaining species only their sum frequency is reproduced.

The occurrence of the aquatic plants *Nymphaea alba* and *Myriophyllum alterni-florum* has been given separately. The greatest frequency of *Nymphaea* appears, as a rule, in the non-calcareous coarse necron mud above the shell-bearing freshwater layer (maximally about 50% of the AP pollen), but it also can be frequent in the shell-bearing sediment. Some pollen grains (obviously in a secondary position) are generally also found in the upper part of the marine clay. *Myriophyllum* pollen grains are more abundant in the shell-bearing freshwater layer (maximally 82%) and occur only occasionally in the coarse necron mud. Secondary *Myriophyllum* pollen grains also occur in the uppermost part of the marine clay.

Descriptions of the localities

The situation and the extent and stratigraphy of the deposits are mentioned. The stratal sequence is chiefly the same in all the localities. The substratum is shell-bearing marine clay (sometimes intermingled with sand). Above this stratum is often a thin layer of yellowish lagoon clay; sometimes the marine layer is overlain by a thicker non-fossiliferous stiff grey clay (Fossane). Thereupon follows the shell-bearing freshwater layer which is more or less calcareous. It may be a greyish calcareous necron mud or a whitish lake chalk. This is overlain by non-calcareous coarse

necron mud which, in turn, continues in deciduous fen-wood peat. This is succeeded by *Sphagnum* peat.

Some abbreviations as regards boundaries in the stratal sequences have been used in text and diagrams. *MLB* stands for the marino-limnic boundary and *LTB* for the limno-telmatic boundary. The lower boundary of the shell-bearing freshwater layer is called *SI* and the upper *SII*. *SI* is practically identical with the *MLB*. *SII* is the boundary against the non-calcareous coarse necron mud.

It happens that there are differences in thickness of the shell-bearing freshwater layers in the pollen diagrams and the other diagrams. This is because of the fact that the pollen samples could not always be taken at exactly the same point as the other samples had been taken about 10 years earlier since these areas were under water on account of heavy rains.

The quantities of the samples examined as well as the percentages of calcium carbonate, phytogene substances and minerogene particles in the fraction < 0.5 mm are given. The composition of the fauna is recorded under the heads of "Ostracods", "Molluscs", and "Other freshwater organisms", respectively. Marine organisms in the freshwater sediment are mentioned under the head of "Marine organisms". Finally, accounts of observations of the vegetation are given.

The origin of the calcium carbonate and the procedure of dating are discussed.

In those cases where the data of frequency are not given as a per cent, they refer invariably to a quantity of 100 g sediment (dry state).

As for nomenclature, I follow, regarding

the plants	HYLANDER 1941
the ostracods	G. O. SÆRS 1922–1928
the molluscs	EHRMANN 1933

The authors of the species are mentioned in the chapter "Survey of the constituents" . . . (p. 142 f.).

The age of the localities is indicated in the following scheme:

	Pm^1	$BM^{inf.}$	C^0	A^0
		$BM^{sup.}$		
Flöghult (118)	—			
Klingseröd II (97)	—			
Askeröd (99)	—		—	
Kålstad (89)	—		—	—
Rabbalshede (94)	—		—	—
Branstaby (90)	—		—	—
Klingseröd I (100)	—		—	—
Stuvängen (65)	—		—	—
Hjelpedsten (68)	—		—	—
Korndalen (71)	—		—	—
Fossane (77)	—		—	—

The figures in () are referable to the height above the sea.

The significance and age of the Pm^1 , $BM^{inf.}$, $BM^{sup.}$, C^0 , and A^0 appear from the discussion of the pollen diagrams, p. 108 f.

Flöghult

Skee parish: from the innermost part of the Idefjord N 75° W, 4.1 km; soil surface 118 m above the sea.

This shell-bearing deposit was observed during the research of peat soils by the Geological Survey (v. POST 1923, map no. 61, locality no. 13). The sequence of strata is described in this work.

The freshwater calcium carbonate may originate from the underlying shell-bearing clay, but possibly also from shells in other marine beds in the vicinity, such deposits being not uncommon.

The calcareous necron mud is about 25 cm thick and is situated 5.60–5.85 m below the peat surface.

It is superimposed by a thin layer of non-calcareous necron mud (about 25 cm), which in turn is overlain by fen peat (2.35 m) and *Sphagnum* peat (3 m).

A sample of 73 g weight was taken up with a can-auger. The content of calcium carbonate of the sample amounted to 9 per cent and the content of phytogene and minerogene particles came to 10 and 81 per cent respectively.

Fauna

Ostracods. One shell belonging to the genus *Candona* was observed.

Molluscs. The frequency of shells is 190 per 100 g sediment. The shells are referable to the following species (percentage distribution):

<i>Succinea</i> sp.....	4
<i>Lymnaea ovata</i>	10
» <i>auricularia</i>	2
<i>Stagnicola palustris</i>	3
<i>Gyraulus arcticus</i>	66
<i>Armiger crista</i>	1
<i>Pisidium</i> spp.	14
» <i>nitidum</i>	(12)
» <i>obtusale</i>	(2)

Other freshwater organisms. One cocoon of *Dendrocoelum* cf. *lactum*.

Marine organisms. One shell of a juvenile specimen of *Hydrobia* and some fragments of *Mytilus*.

Vegetation

Fruits exclusively belonging to the genus *Potamogeton* were observed (*P. pectinatus* 6; *P. natans* 6; and *P. praelongus* 3).

Oospores of Charophytes are pretty common. They are partly encrusted with calcium carbonate.

Age

Pollen diagram Pl. I, Fig. 1.

The *BM* is distinct, occurring exactly at the top of the shell-bearing layer.

Below the *BM* (at the *MLB*) there is a distinct *Pinus* maximum which may correspond to the *Pm*¹ (cf. p. 109).

The shell-bearing stratum may thus have been formed when the Ice receded from the Bergslagen to Jämtland, i. e. during the later part of the Finiglacial period.

Klingseröd II

Kville parish: from the Rabbalshede railway station N 35° E, 3.4 km; soil surface 97 m above the sea.

The shell-bearing layer consists of calcareous necron mud and lake chalk (maximally 50 cm thickness). It is overlain by coarse necron mud (30 cm) and underlain by blue clay including numerous marine molluscs.

Immediately above the *MLB* there are abundant macro-remnants of plants. Next upon this layer follows almost white lake chalk with a high percentage of calcium carbonate (Pl. III, Fig. 1) and numerous shells and remnants of plants.

The freshwater calcium carbonate may originate from the above-mentioned shell-bearing clay and from other shell-bearing marine clays in the vicinity.

For analyses a pillar was dug out from an exposed profile and divided into the following 4 samples:

Sample no.	Height	Weight
4	14 cm	119.5 g
3	12 »	105.6 »
2	12 »	103.5 »
1	11 »	108.0 »

Fauna

Ostracods. One single shell of an ostracod referable to the genus *Candona* was observed in sample no. 1.

Molluscs. As appears from Pl. III, Fig. 2, the frequency of shells increases upwards; the maximum with about 7000 shells per 100 g sediment was reached just below the *S II*.

Valvatidae and Planorbidae dominate among the mollusc families (Pl. III, Fig. 3). The former attains a very distinct maximum just above the *MLB* and another immediately below the *S II*. In the middle of the layer the frequency is low. On the contrary, the family Planorbidae is characterized by an important maximum exactly in this section. The families Sphaeriidae and Lymnaeidae are more rarely represented. Sphaeriidae has a rather even frequency throughout the whole layer; Lymnaeidae attains a small maximum in sample 3. The families Physidae with *Physa fontinalis* and Ancyliidae with *Acroloxus lacustris* are represented in small numbers. The table below gives their percentage frequency:

	1	2	3	4
<i>Physa fontinalis</i>	—	1	1	1
<i>Acroloxus lacustris</i>	+	+	2	1

The family Valvatidae is represented by two species, *Valvata cristata* and *V. piscinalis*. The former is the most abundant. The maxima of the two species coincide, viz. immediately above the *MLB* and just below the *S II*. As illustrated in Pl. III, Fig. 4 the minimum of *Valvata cristata* comes before that of *V. piscinalis*. The family Planorbidae is represented by *Gyraulus arcticus*, *Gyraulus albus*, *Armiger crista* (f. *typica* and f. *nautilea*), and *Hipppeuthis complanatus* (Pl. III, Fig. 5). *Armiger*

crista is the dominating species among those having important maxima both in the bottom and the top of the layer. *Hippeuthis complanatus* occurs, likewise, throughout the whole layer, but reaches its maximum in sample 3. *Gyraulus albus* occurs in the three lowest samples. This species has its highest frequency in the middle of the stratum.

The family Sphaeriidae is represented by *Sphaerium corneum* and by species belonging to the genus *Pisidium*. The following table indicates their respective percentage shares in the total number of shells:

	1	2	3	4
<i>Sphaerium corneum</i>	3	3	7	1
<i>Pisidium</i> sp.	—	+	1	+

The distribution of the *Pisidium* species is shown in Pl. III, Fig. 6. *P. nitidum*, *P. milium*, and *P. obtusale* occur in considerable numbers through the whole layer. Furthermore, these species show a great conformity in their representation; they have maxima in the lowest as well as in the topmost section of the stratum. In this respect they are reminiscent of the two species of *Valvata* in this deposit. *P. milium* is almost exclusively represented by the variety *unioides*; *P. henslowianum* which is completely absent in the other samples is abundant in sample 3. *P. hibernicum* and *P. liljeborgi* occur only in small numbers. They are, however, represented through the whole layer, reaching their maximal frequency in the lower part of the bed. *P. subtruncatum* is absent in the uppermost sample. This species has a rather even frequency in the other parts of the stratum.

Other freshwater organisms. In sample no. 1 a single cocoon of *Dendrocoelum* cf. *lacteum* was observed; in nos 1, 2, and 4 statoblasts of *Cristatella* cf. *mucedo*; in nos. 1 and 4 chitin of insects; and in no. 3 remnants of fish skeletons.

Marine organisms. Especially in the bottom sample, rather many marine species were observed (*Mytilus edulis*, *Cardium edule*, *Hydrobia* cf. *ulvae* and *Balanus* cf. *balanus*). Species of *Elphidium* occur even as high as in the second sample from the top.

Vegetation

Remains in considerable numbers — especially vegetative components — of the obviously abundant vegetation in the ancient lake have been preserved. Seeds of the following species were observed.

	1	2	3	4
<i>Potamogeton obtusifolius</i>	5	—	—	2
» <i>pectinatus</i>	3	—	—	—
<i>Scirpus lacustris</i>	2	5	8	—
<i>Carex</i> cf. <i>hornschuchiana</i>	—	—	1	—
» sp.	—	—	4	—
<i>Ranunculus</i> sp.	—	1	—	—
<i>Nymphaea alba</i>	—	—	3	—
<i>Comarum palustre</i>	—	1	—	1
<i>Menyanthes trifoliata</i>	2	—	—	—

Gramineal seeds were observed in the samples 1 and 3.

Oospores of Charophytes are common in the bottom sample and rather common in the others. They have no calcareous covering.

Age

Pollen diagram Pl. I, Fig. 6.

The $BM^{sup.}$ and the C^0 were developed during the latest part of the formation of the shell-bearing layer. The A^0 appears somewhat higher. The sedimentation of this stratum had begun contemporaneously with the appearance of the $BM^{inf.}$.

The layer was thus accumulated during the transition from the Finiglacial to the Postglacial period.

Askeröd

Kville parish: from the Rabbalshede railway station N 50° E, 2.9 km; soil surface 99 m above the sea.

The calcareous freshwater layer is included in the following stratal sequence:

1. Deciduous fen-wood peat 180 cm
2. Coarse non-calcareous necron mud 65 »
3. Calcareous necron mud with shells 55 »
4. Shell-bearing sandy, marine blue clay.

The freshwater calcium carbonate certainly originates to a large extent from the shell-bearing clay, but also from other shell-bearing marine sediments situated somewhat N of the freshwater deposit.

Three samples were taken up with a can-auger: one from the upper part of the shell-bearing layer (no. 1), and two others from its middle part (nos. I and II). The weights amounted to 122, 58, and 196 g respectively.

The percentage frequencies of phytogene and minerogene particles and of calcium carbonate were as follows:

	Phyt. comp.	Min. comp.	Calcium carbonate
Sample I	6	14	80
» II	9	31	60
» I	11	9	80

Fauna

Ostracods. Shells of ostracods are very rare; two shells only, belonging to the genus *Candona*, were observed in sample no. 1.

Molluscs. The frequency of shells was:

Sample no. I	2140
» » II	3260
» » I	2220

I. HESSLAND, *Calcareous freshwater sediments from northern Bohuslän*

The percentage distribution of the species was:

	I	II	I
<i>Succinea</i> sp.	—	+	—
<i>Lymnaea ovata</i>	2	1	2
» <i>auricularia</i>	—	—	+
<i>Gyraulus arcticus</i>	30	46	19
» <i>albus</i>	—	+	+
<i>Armiger crista</i>	27	39	19
<i>Hippeuthis complanatus</i>	2	1	6
<i>Acroloxus lacustris</i>	2	1	2
<i>Valvata cristata</i>	11	2	16
» <i>piscinalis</i>	+	+	+
<i>Pisidium</i> spp.	26	10	36
» <i>nitidum</i>	(5)	(2)	(8)
» <i>lilljeborgi</i>	(2)	(1)	(3)
» <i>milium</i>	(7)	(2)	(10)
» <i>subtruncatum</i>	(1)	(+)	(2)
» <i>obtusale</i>	(11)	(5)	(10)
» <i>hibernicum</i>	—	(+)	(2)
» sp.	(+)	—	(1)

Pisidium milium is represented by the variety *unioides* to a great extent. The low frequency of *Lymnaea ovata* is remarkable.

Other freshwater organisms. Statoblasts of *Cristatella* cf. *mucedo* occur in the numbers of 2, 17, and 20 in samples 1, I, and II, respectively. Eggs of *Turbellaria rhabdocoela* were observed in samples 1 and II; cocoons of *Chaetogaster* sp. in no. II; and remains of fish skeletons in no. I.

Marine organisms. Fragments of *Mytilus* and *Balanus* as well as shells of *Elphidium* were found in samples nos. I and II. A shell of a juvenile *Littorina littorea* occurred in no. I. No marine organisms were observed in no. 1.

Vegetation

The sediment is characterized by abundant phanerogamous remains. Seeds of the following species were discerned:

	I	II	I
<i>Potamogeton natans</i>	74	14	72
» <i>gramineus</i>	—	—	1
» <i>praelongus</i>	2	1	—
<i>Scirpus lacustris</i>	3	1	5
» <i>maritimus</i>	—	1	—
<i>Carex</i> sp.	—	1	—
<i>Nymphaea alba</i>	—	—	2
<i>Ranunculus</i> sp.	2	—	—
<i>Menyanthes trifoliata</i>	—	—	1

Oospores of Charophytes occur rarely in all samples; they have no covering of calcium carbonate.

Age

Pollen diagram Pl. I, Fig. 2.

The *BM^{sup.}* appears in the upper half of the shell-bearing layer which, judging from the appearance of the sediment, may have accumulated rather rapidly. The *C⁰* is about contemporaneous. The *A⁰* is situated far higher up. The bottom part of the layer was developed at the same time as the *BM^{inf.}*.

The layer was thus formed during the transition from the Finiglacial to the Post-glacial period.

Kålstad

Tanum parish: from the Tanum church N 45° E, 4.8 km; soil surface 89 m above the sea.

This deposit of calcareous freshwater sediments is the most important observed within the area examined. It includes about 2 hectares. The sediment consists of calcareous necron mud and lake chalk. The thickness amounts to 60-95 cm. It is overlain by coarse necron mud (about 25 cm in thickness) and deciduous fen-wood peat which is under cultivation at the present day.

The calcareous stratum is underlain by shell-bearing marine clays. In the immediate vicinity there are also some other shell-bearing marine sediments. The shore of the ancient lake in the south and the south-west consisted of shell-bearing sea sand. Additionally, a shell bed is situated in the area which separated the ancient lake from the sea. The calcium carbonate in the calcareous freshwater stratum is obviously derived from the marine deposits now mentioned.

Between the marine and the pure freshwater sediments there is a layer of clayey necron mud about 1.5 cm thick and greyish-yellow in colour, containing, inter alia, numerous brackish water diatoms. Dr. SANDEGREN in examining one sample observed the following species in the numbers given below:

<i>Gyrosigma spenceri</i>	21
<i>Anomoeoneis sculpta</i>	20
<i>Coscinodiscus</i> sp.	11
<i>Achnantes</i> sp. (<i>brevipes?</i>).....	11
<i>Triceratium antediluvianum</i>	10
<i>Navicula oblonga</i>	6
<i>Diploneis interrupta</i>	4
<i>Epithemia sorex</i>	4
<i>Amphora ovalis</i>	3
<i>Nitzschia punctata</i>	3
<i>Surirella striatula</i>	3
<i>Caloneis limosa</i>	2
<i>Cocconeis pediculus</i>	2
<i>Diploneis didyma</i>	2
<i>Epithemia turgida</i>	2
» <i>zebra</i>	2
<i>Mastogloia braunii</i>	2
<i>Cocconeis placentula</i>	1
<i>Mastogloia smithii</i>	1
<i>Rhopalodia gibba</i>	1

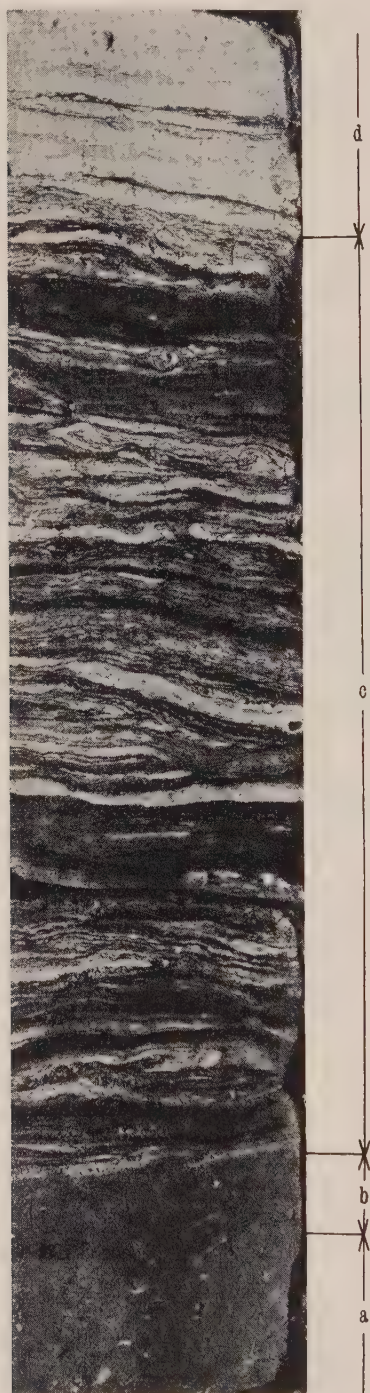


Fig. 2. Profile from the Kålstad deposit, showing uppermost part of marine clay (a), lagoon clay (b), fine lamination of lake chalk (white) and non-calcareous mud (c), chiefly pure lake chalk (d). $2/3 \times$.

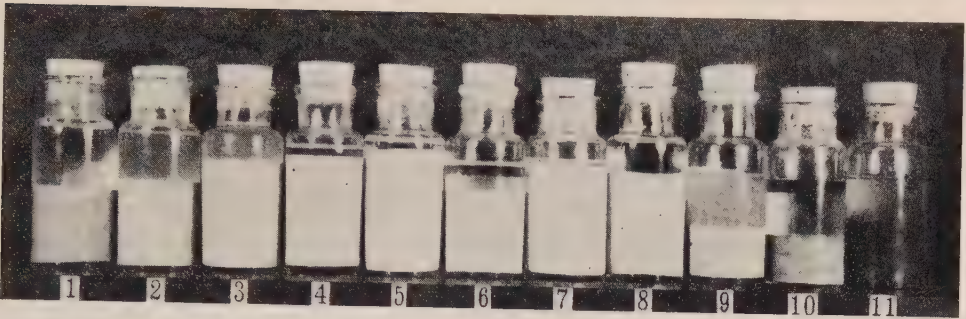


Fig. 3. Particles < 0.5 mm from the Kålstad stratal sequence. Numbers referable to samples investigated; (cf. below).

This clay stratum was obviously deposited in the lagoon which formed the transitional stage between creek and lake. Fish skeletons occur locally in this sediment. They have not been determined as to species. These skeletons originate probably from marine fishes, which had been enclosed in the lagoon and soon succumbed there for want of saltwater.

The bottom part of the freshwater layer shows a pronounced and irregular lamination between strata of non-calcareous necron mud and lake chalk. This lamination disappears about 20 cm above the lagoon sediment and is succeeded by lake chalk containing very thin layers of necron mud, discernible by careful examination.

For analyses a sediment pillar was dug out. It was divided into the following 12 samples:

Sample no.	Height	Weight	
12	3 cm	64 g	Coarse non-calcareous necron mud
11	2 »	60 »	
10	4 »	130 »	
9	6 »	222 »	
8	7 »	165 »	Calcareous freshwater sediments
7	10 »	350 »	
6	9 »	345 »	
5	10 »	400 »	
4	6 »	230 »	
3	6 »	275 »	Lagoon clay
2	4 »	119 »	
1	2 »	131 »	Marine clay

The percentage of calcium carbonate and of phytogene and minerogene particles is reproduced graphically in Pl. III, Fig. 7. The appearance of the fraction < 0.5 mm is shown in Fig. 3. Sample no. 1 is marine greyish-blue clay. Traces of such clay also occur in samples no. 2 (lagoon clay) and no. 3. Samples nos. 4–8, on the other hand, consist of very pure lake chalk with a content of calcium carbonate varying between 97 and 99 per cent. The following samples from 9 to 12 become progressively darker because of a steadily increasing content of phytogene substances. In samples 8–11 the percentage of such substances increases from 1.2 to 23.4 per cent. (In sample 9 the content is 3.0 per cent and in 10, 5.0 per cent.)

Fauna

The Kålstad deposit was not investigated at the same time as the other localities but earlier (1937). The molluscs were investigated quantitatively on that occasion. Later this examination was completed by a qualitative analysis of the material left from the earlier investigation.

Ostracods. Only shells referable to the genus *Candona* were observed. They occur both in the bottom part and in the upper part of the calcareous sediment. The genus is even represented in the marine sample no. 1. This may be explained by the fact that species belonging to the *Candona* group are able to exist in water with rather high salinity (< 1 per cent; ELOFSON 1943). — Sample no. 1 also includes worn shells of the marine species *Cythere lutea*.

Molluscs. The frequency of shells is shown graphically in Pl. III, Fig. 8. From this diagram it appears that the frequency is rather insignificant in the lowermost third of the shell-bearing layer; but then it increases and attains very high values in the uppermost third. Thus, in samples nos. 9 and 10 about 1660 and 1620 shells respectively per 100 g sediment were counted. A comparison with the curve of the calcium carbonate shows that the maximum of shell frequency does not coincide with the maximum of calcium carbonate.

The distribution of the mollusc families is illustrated in Pl. III, Fig. 9. The family Sphaeriidae — represented chiefly by species of the genus *Pisidium* — is characterized by a high frequency through the whole shell-bearing layer. A very pronounced maximum occurs just below the *S II*, viz. in sample no. 10 (about 1200 shells per 100 g sediment). In connection with the rise of this maximum, *P. milium* loses the dominating position which it has held right from the bottom samples in favour of *P. nitidum* (Pl. III, Fig. 10). *P. lilljeborgi* makes its first appearance in the latter half of the shell-bearing layer, whilst *P. hibernicum* shows a rather constant frequency all the time. *P. subtruncatum* is represented in the lower part as well as in the top section. Furthermore, shells of *P. obtusale* were observed at the qualitative examination just mentioned. They occur chiefly in the very lowest part of the calcareous layer but are also represented in its upper part. In addition to *Pisidium*, the family Sphaeriidae is also represented by *Sphaerium corneum*. Some shells of this species were observed in both the bottom and the top sections of the deposit.

The family Lymnaeidae also attains a high frequency and has a distinct maximum somewhat below that of Sphaeriidae, viz. in sample no. 9 (605 individuals per 100 g sediment). The family is represented almost exclusively by *Lymnaea ovata* which shows a considerable individual variation. In addition to shells of the main type, numerous shells appear varying towards f. *peregra* (*Lymnaea peregra* MÜLLER) as well as towards f. *lagotis* (*Lymnaea lagotis* SCHRANK). F. *peregra* is distinguished by its rather high spire (the height at least half of the aperture width), f. *typica* by its low spire (less than one third of the width of the aperture). Regarding these characters, f. *lagotis* holds an intermediate position (cf. HUBENDICK 1945). Additionally, the angle between the outer lip of the aperture and the parietal wall varies. F. *peregra* and f. *typica* have an acute or sometimes a square angle, but in f. *lagotis* it is generally square or obtuse. The majority of the types occurring here show greater conformity with f. *typica* and f. *peregra* in this respect than with f. *lagotis*. — A few shells of *Lymnaea auricularia* were found.

The family Valvatidae, here exclusively represented by *Valvata cristata*, appears

through the whole layer. Its maximum occurs below that of Lymnaeidae, viz. in sample no. 8 (132 individuals per 100 g sediment).

The maximal frequency of the family Planorbidae occurs simultaneously with that of Valvatidae (80 individuals per 100 g sediment). Planorbidae is represented by three species: *Armiger crista*, *Gyraulus arcticus*, and *Hippeuthis complanatus* (Pl. III, Fig. 11). *Armiger crista* appears both as f. *typica* and f. *nautila*. The latter variety has a considerably higher frequency than f. *typica* through the whole layer. *Gyraulus arcticus* occurs throughout the layer. On the other hand, *Hippeuthis complanatus* was observed in the upper part and only in the quantitative analysis. However, in a qualitative examination of samples from another point of the shell-bearing area, *Hippeuthis* was found also in the lower part. The frequency maximum of the family Planorbidae is, above all, caused by the two first-mentioned species.

The family Physidae is sparingly represented in the upper part of the layer by *Physa fontinalis*. This species was not observed in the lower sections.

Two specimens of *Acrolorus lacustris*, family Ancyliidae, were observed, one in the top section and one in the bottom part of the layer. Both of them measure 4 mm.

Other freshwater organisms. In the qualitative examination, one ephippium of *Daphnia pulex* was observed in sample no. 2. Statoblasts of *Cristatella* cf. *mucedo* appear in the lowest as well as in the topmost parts of the layer. A fairly well preserved coleopter was embedded in no. 4. Remains of fish skeletons sometimes occur in the lagoon stratum (cf. p. 119).

Marine organisms. In the marine sample no. 1 numerous shells of *Mytilus edulis*, *Littorina littorea*, *Nonion labradoricum*, and *Elphidium* spp. were preserved. As already mentioned, shells of *Cythere lutea* were also found there.

Vegetation

The frequency of Characaeal oospores was especially examined throughout the stratum. The result is shown in Pl. III, Fig. 12. The oospores begin to appear, very rarely, as early as in the marine sample no. 1. After some fluctuations in the lower part their frequency curve rises to a distinct maximum in the upper half of the layer immediately below the *S II*. This maximum is attained just before the maximum of the mollusc shells, and coincides most closely with the highest frequency of the Lymnaeidae. The oospores are encrusted with calcium carbonate to a great extent, except those in sample no. 11 which are devoid of any calcareous covering.

Vegetative components from the phanerogameous vegetation are numerous in all samples. Neither these remains nor the fruits were examined during the investigation in 1937. At the re-investigation of the remaining material fruits were observed in the top and bottom samples. *Scirpus lacustris* and seeds of *Nymphaea alba* were found in samples nos. 10 and 11. Additionally, seeds of *Carex* sp. and *Betula* sp. occurred in sample no. 10 and fruit kernels of *Arctostaphylos uva ursi* in sample no. 11.

Age

Pollen diagram Pl. I, Fig. 4.

The bottom-most part of the shell-bearing layer is somewhat older than the *BM^{sup.}*; the *BM^{inf.}* is situated somewhat below the *MLB*. The *C⁰* appears about contemporaneously with the *BM^{sup.}*. The *A⁰* was developed somewhat after the formation of the calcareous freshwater layer had ceased.

Thus, the formation of the shell-bearing stratum began at the transition between the Finiglacial and Postglacial periods and continued for some centuries to about 6300 B. C. It corresponds mainly to the great Boreal hazel maximum.

Rabbalshede

Kville parish: the Rabbalshede railway station, immediately N of the station-house; soil surface 94 m above the sea.

At least partially, the railway yard is built on peat soil. It was observed that the peat north of the station-house is underlain by calcareous freshwater sediments. Just east of the rails and parallel with them this layer could be followed for some 40 m. For the greater part of its extent the calcareous stratum has a thickness of about 30–40 cm. The overlying coarse necron mud is 7–8 cm and the covering peat layer is about 80 cm thick. The freshwater stratum is underlain by shell-bearing marine clay.

The freshwater calcareous carbonate certainly originates from shells in the marine clay and from other shell-bearing marine strata in the vicinity.

The following samples were taken from the exposed profile for the various analyses:

Sample no.	VI	280	g (shell-bearing calcareous freshwater necron mud)
»	»	V	591.5 » (upper part of the calcareous necron mud)
»	»	IV	130 » —»—
»	»	III	593 » —»—
»	»	II	16.2 » (middle part of the calcareous necron mud)
»	»	I	399 » (bottom part of the calcareous necron mud)

The percentage distribution of the phytogene and minerogene particles and of calcium carbonate was as follows:

	Phyt. comp.	Min. comp.	Calcium carbonate
Sample no. VI	9	58	33
» » V	11	66	23
» » IV	46	23	31
» » III	6	58	36
» » II	5	60	35
» » I	10	60	30

Fauna

Ostracods. Shells of ostracods were observed in all samples. The following species were found:

	I	II	III	IV	V	VI
<i>Candona</i> sp.	37	6	10	17	1	27
<i>Cythere lutea</i>	7	—	—	—	—	—
<i>Hemicythere emarginata</i>	2	—	—	—	—	—

Cythere and *Hemicythere* are marine.

Molluscs. Frequency of shells:

Sample no. VI	195
» » V	410
» » IV	530
» » III	250
» » II	210
» » I	310

The percentage distribution of the molluscs was:

	I	II	III	IV	V	VI
<i>Lymnaea ovata</i>	40	47	28	38	41	21
<i>Stagnicola palustris</i>	5	6	3	6	5	4
<i>Gyraulus arcticus</i>	26	18	27	41	26	26
» <i>albus</i>	+	—	—	—	—	—
<i>Armiger crista</i>	1	3	2	4	1	1
<i>Sphaerium corneum</i>	—	—	—	—	+	—
<i>Pisidium</i> spp.	28	26	40	11	27	48

The percentage distribution of Pisidia was:

	I	II	III	IV	V	VI
<i>Pisidium nitidum</i>	66	60	71	65	62	67
» <i>lilljeborgi</i>	8	—	2	2	3	3
» <i>subtruncatum</i>	8	—	6	4	12	9
» <i>hibernicum</i>	2	—	1	4	5	5
» <i>obtusale</i>	8	—	8	8	6	7
» <i>milium</i>	8	40	12	17	12	9
» » <i>f. unioides</i>	—	(20)	(4)	(6)	(4)	—

In some cases there is good conformity as to the frequency of the species in the samples from the upper part of the calcareous layer. In other cases there are divergences, certainly in part depending on the circumstance that all the samples were not taken from exactly the same depth below the *S II*. From the tables it appears that *Lymnaea ovata*, *Gyraulus arcticus*, and *Pisidium nitidum* are dominating species. The frequency of *Pisidium nitidum* is strikingly equal in all samples; that of *Lymnaea* and *Gyraulus* shows greater fluctuations. The highest frequency of *Lymnaea ovata* — as well as of the rather abundant *Pisidium milium* — and the lowest frequency of *Gyraulus arcticus* occur in the middle of the layer. The variety *unioides* forms a considerable proportion of the *P. milium* shells.

Other freshwater organisms. One ephippium of *Daphnia pulex* was observed in no. VI; statoblasts of *Cristatella* cf. *mucedo* in all samples, exclusive of no. V; and remains of fish skeletons in nos. I and VI.

Marine organisms. Remains of marine organisms were observed in samples I, III, IV, V, and VI; fragments of *Mytilus* shells in all samples except no. II; young *Littorina* shells in nos. IV and VI; a spine of an echinoid and a fragment of *Balanus* sp. in no. I.

Vegetation

Rather many remains of the higher vegetation of the ancient pond — especially fruits and seeds — are preserved. The following species are represented:

	I	II	III	IV	V	VI
<i>Potamogeton pectinatus</i>	68	91	39	—	27	11
» <i>obtusifolius</i>	—	1	—	—	—	—
<i>Carex</i> spp.	3	6	2	6	1	3
<i>Polygonum</i> sp.....	—	—	1	—	—	—
<i>Ranunculus</i> cf. <i>peltatus</i>	1	—	—	—	—	—
» sp.	—	—	—	—	—	1
<i>Myriophyllum spicatum</i>	1	1	4	—	4	3
<i>Hippuris vulgaris</i>	—	—	—	—	—	1
<i>Empetrum nigrum</i>	—	—	—	—	—	1
<i>Menyanthes trifoliata</i>	—	1	—	—	—	—

Oospores of Charophytes appear in all samples without being especially numerous, except in one sample. They are not encrusted with calcium carbonate.

Age

Pollen diagram Pl. I, Fig. 5.

The shell-bearing layer began to be formed somewhat earlier than the $BM^{sup.}$ was developed and somewhat later than the $BM^{inf.}$. The C^0 appears in the upper section of the layer. The A^0 was developed just as the accumulation of the calcareous freshwater sediment ceased. The T^0 occurs in the lower part of the fen peat.

The shell-bearing layer was obviously accumulated during a period beginning at the transition from the Finiglacial and continuing for some few centuries during the first part of the Postglacial period (to about 6300 B. C.).

Branstaby

Kville parish: from the Rabbalshede railway station S 5° W, 2.0 km; soil surface 90 m above the sea.

The shell-bearing layer forms a part of the substratum of the vast peat moss near the Branstaby farm. It consists of calcareous necron mud as also mentioned earlier (v. Post 1923, map no. 51, locality no. 46) but also partly of lake chalk; the stratal sequence is described on p. 9 in v. Post's paper.

The calcareous layer occurs only within limited areas. The following stratal sequence was observed by me:

1. Deciduous fen-wood peat..... 180 cm
2. Coarse non-calcareous necron mud 45 »
3. Calcareous necron mud 40 »
4. Yellowish-grey brackish water calcareous clay with necron mud. 5 »
5. Marine blue clay.

In another section of the mire, the peat — resting immediately on marine blue clay — is 6.5 m thick.

The freshwater calcium carbonate may have derived from shells in the marine clay to a great extent, but also from other shell-bearing marine deposits in the vicinity.

Three samples of the calcareous sediment were analysed: no. 2 from the bottom-most part of the stratum, no. 3 from the middle part, and no. 4 from the uppermost section. One sample of marine clay (no. 1) was examined. The result of a qualitative faunistic examination performed earlier is also given (no. V).

Quantities analysed were:

Sample no. 4	169 g
» » 3	73.5 »
» » 2	24.5 »
» » 1	218 »

The table below illustrates the percentage of phytogene and minerogene constituents and the percentage of calcium carbonate:

	Phyt. components	Min. components	Calcium carbonate
Sample no. 4	50	19	31
» » 3	8	73	19
» » 2	7	75	18
» » 1	2	92	6

Fauna

Ostracods. Shells of ostracods are almost completely absent in the samples examined. In sample 4 a shell belonging to the genus *Candona*, and in no. 1 a few shells of the marine species *Cythere lutea* were found.

Molluscs. The frequency of the molluscs was:

Sample no. 4	1180
» » 3	480
» » 2	310
» » 1	—

The percentage distribution of the molluscs was:

	2	3	4	V
<i>Lymnaea ovata</i>	23	42	19	14
<i>Physa fontinalis</i>	—	+	—	+
<i>Gyraulus arcticus</i>	23	35	9	1
» <i>albus</i>	—	—	1	1
<i>Armiger crista</i>	14	7	17	22
<i>Hippeuthis complanatus</i>	—	1	3	2
<i>Acroloxus lacustris</i>	—	—	+	+
<i>Valvata cristata</i>	14	—	19	38
» <i>piscinalis</i>	7	—	12	6
<i>Sphaerium corneum</i>	1	2	2	—
<i>Pisidium</i> spp.	18	13	18	16
» <i>nitidum</i>	(5.5)	(3.4)	(10.7)	(8.8)
» <i>lilljeborgi</i>	—	—	(1.6)	(0.3)
» <i>subtruncatum</i>	—	(2.3)	(1.2)	(1.2)
» <i>hibernicum</i>	(1.4)	(0.3)	(0.3)	(0.9)
» <i>obtusale</i>	(1.4)	(0.5)	(0.6)	(0.4)
» <i>milum</i>	(9.7)	(6.5)	(3.6)	(4.4)

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This table shows that certain species reach their highest frequency in the middle of the shell-bearing stratum (sample no. 3). Others, again, are more abundant in the bottom part (2) and in the upper section (4). To the former group belong:

Lymnaea ovata
Physa fontinalis
Gyraulus arcticus
Pisidium subtruncatum

The latter group consists of:

Armiger crista
Valvata cristata
» *piscinalis*
Pisidium nitidum
» *obtusale*

The frequency of other species increases towards the upper part of the deposit, viz:

Gyraulus albus
Hippeuthis complanatus
Acroloxus lacustris
Sphaerium corneum
Pisidium lilljeborgi

Finally, the frequency of the following species decreases towards the top:

Pisidium hibernicum
» *milium*

Other freshwater organisms. Ephippia of *Daphnia pulex* appear in samples nos. 4 (3 in number) and V (2 in number); eggs of rhabdocoels in samples nos. 1, 2, and 3 (5, 8, and 2 respectively); cocoons of *Dendrocoelum* cf. *lacteum* in nos. 1 and 4; statoblasts of *Cristatella* cf. *mucedo* and chitin of insects in nos. 2, 3, 4, and V (16, 10, 5 and 7 respectively); and, finally, remains of fish skeletons in nos. 3, 4, and V.

Marine organisms. Fragments of *Mytilus* shells were observed in all samples except no. 4. Also, shells of *Elphidium* spp. and *Nonion labradoricum* as well as fragments of *Balanus* sp. and shells of *Macoma calcarea* occur in no. 1. Additionally, during pollen analysis some few marine diatoms were found in no. 2.

Vegetation

Fruits of rather many species were observed; but the vegetation in the ancient lake does not seem to have been very abundant.

As the biogene components in sample no. V are not referable to a certain quantity, the percentage distribution of seeds in all samples is given in parentheses; as usual, the other figures represent the frequency in numbers per 100 g of sediment.

Oospores of Charophytes are common in all samples, with the exception of no. 1 where they are fairly rare.

	1	2	3	4	V
<i>Potamogeton pectinatus</i>	—	—	—	2 (22)	(1)
» <i>gramineus</i>	—	—	1 (3)	1 (11)	(31)
» <i>natans</i>	—	—	1 (3)	1 (11)	(8)
? <i>Catabrosa aquatica</i>	—	1 (17)	—	—	(1)
<i>Scirpus maritimus</i>	4 (100)	—	18 (46)	1 (11)	(5)
» <i>lacustris</i>	—	—	10 (23)	1 (11)	(36)
» sp.	—	—	4 (10)	—	(2)
? <i>Rhynchospora alba</i>	—	—	—	1 (11)	—
<i>Carex</i> cf. <i>stellulata</i>	—	1 (17)	—	—	—
» sp.	—	1 (17)	4 (10)	1 (11)	(11)
<i>Nymphaea alba</i>	—	—	1 (3)	1 (11)	(3)
<i>Comarum palustre</i>	—	1 (17)	—	—	—
<i>Myriophyllum spicatum</i>	—	1 (17)	—	—	—
» cf. <i>alterniflorum</i>	—	1 (17)	—	—	—
<i>Naumburgia thyrsiflora</i>	—	—	—	—	(2)

Age

Pollen diagram Pl. I, Fig. 7.

The exact position of the *BM*^{sup.} is not perfectly known, but most probably it is indicated by the high *Betula* values at the marino-limnic boundary. The shell-bearing layer was formed previously to the great Boreal hazel maximum; the *C*⁰ appears in the uppermost part of the layer. The *A*⁰ was developed during the formation of the fen peat.

The layer was thus accumulated during the very first part of the Postglacial period.

Klingseröd I

Kville parish: from the Rabbalshede railway station N 48° E, 3.3 km. This locality is identical with the mire no. 56 in v. Post 1923 (map no. 51). Soil surface 100 m above the sea.

Calcareous necron mud and lake chalk are included in a sequence of strata of the following type:

1. Deciduous fen-wood peat 100–200 cm
2. Coarse non-calcareous necron mud 65 »
3. Lake chalk and calcareous necron mud 40–75 »
4. Marine, shell-bearing blue clay.

The calcareous freshwater stratum covers an area of at least 1/4 hectare. The freshwater calcium carbonate obviously originates from the subjacent shell-bearing clay and from other nearby marine deposits.

A sediment pillar from the shell-bearing freshwater deposit was examined. It was divided into 10 samples:

Sample no.	Height	Weight
10	2 cm	42,3 g
9	3 »	59.1 »
8	6 »	71.4 »

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Sample no.	Height	Weight
7	14 cm	154.5 g
6	16 »	158.8 »
5	3 »	22.2 »
4	10 »	132.3 »
3	6 »	58.2 »
2	11 »	103.8 »
1	4 »	48.8 »

As appears from Pl. II, Fig. 2 the percentage of calcium carbonate increases rather rapidly to important values. The percentage of minerogene particles decreases contemporaneously. In the bottom part of the calcareous layer there occur considerable quantities of remains from the higher vegetation of the ancient pond. These plant remains are interstratified with highly calciferous layers in the same way as described from the Kålstad deposit (p. 119, also cf. Fig. 2). (The sudden decrease of the calcium carbonate content in sample no. 5 is caused by coarse plant remains to a very great extent.) In the upper half of the layer the lake chalk is very pure and white, but towards the *S II* it becomes mixed up with steadily increasing quantities of minerogene and phytogene particles. Via calcareous necron mud clay full of remains of the higher vegetation the lake chalk is finally succeeded by coarse non-calcareous necron mud.

In the lowest part the total curve of the components < 0.5 mm is chiefly formed by minerogene fine-particles (Pl. II, Figs. 1 and 2). In the remaining part, however, it is mainly formed by the curve of the calcium carbonate.

Fauna

Ostracods. Shells were observed in small numbers in the following samples:

	1	2	3	4	5	6
<i>Pionocypris vidua</i>	—	—	—	—	—	1
<i>Candona</i> sp.	—	2	—	—	1	15
<i>Cythere lutea</i>	8	7	2	1	—	—

Molluscs. The shell frequency is shown in Pl. II, Fig. 3 and the frequency of the families in Pl. II, Fig. 4.

From the former curve it is evident that the shell frequency is high in all sections. Four maxima can be distinguished: in the bottom section is a less important lower one besides an upper one, which represents the absolute maximum (nearly 10 000 per 100 g of sediment); the upper section is distinguished by a more important lower maximum and a less important upper one, the latter situated immediately below the *S II*.

The mollusc families consist of one group with numerous shells and another with low shell frequency. The former includes the families Lymnaeidae, Planorbidae, Valvatidae, and Sphaeriidae, the latter the families Physidae and Ancyliidae. The family Planorbidae very soon gained a dominating position in the fauna of the ancient pond, but was later forced to retire successively in favour of other families, espe-

cially Sphaeriidae, which dominates in the upper part of the shell-bearing sediment. In the upper section the frequency curve of the family Lymnaeidae shows striking conformity with that of Sphaeriidae. In the lower section of the deposit the two curves correspond to some degree, with the exception, however, that a maximum occurring in both curves — in both cases succeeded by a considerable minimum — does not take place simultaneously; the changes of the Sphaeriidae curve occur somewhat earlier. The family Valvatidae has a remarkable representation. In sample no. 1 it shows a slight maximum, but is then so poorly represented up to sample no. 6 that its frequency does not even amount to as much as 0.5 per cent. During the last period of the existence of the ancient lake, however, the family reached a rather considerable frequency and attained a marked maximum immediately below the *S II*. This occurred after the time when the number of individuals of those families which until then had been in the majority was strongly decreasing.

Lymnaeidae is represented by one species only, viz. *Lymnaea ovata*, which, besides occurring in the main type, also occurs in types varying towards *f. peregra* as well as towards *f. lagotis* (cf. p. 120). The shells belonging to the family Valvatidae are almost exclusively referable to *Valvata cristata*; *Valvata piscinalis* occurs in samples nos. 2, 6, and 7 with a percentage < 0.5 . The family Planorbidae, on the other hand, is represented by three species, viz. *Gyraulus arcticus*, *Armiger crista*, and *Hippeuthis complanatus*. The distribution of these three species is shown in Pl. II, Fig. 5. *Gyraulus arcticus* and *Armiger crista* occur from the *MLB* and up to the *S II*. They very soon reached a high frequency. In the lower half of the layer, however, the reciprocal frequency changes strongly, inasmuch as a maximum of one species usually corresponds to a minimum of the other. In the upper half of the deposit the frequency curve of *Gyraulus arcticus* gradually and continuously decreases. This also applies to the *Armiger crista* curve, which decreases gradually as far as a horizon immediately below the *S II*, where, like *Valvata cristata*, it reaches a sudden and pronounced maximum. *Hippeuthis complanatus* was only observed in the upper part of the layer, where, however, it occurs with a high frequency.

The family Sphaeriidae is represented by the genera *Sphaerium* and *Pisidium*; *S. corneum* is the only *Sphaerium* species present. Its frequency curve is characterized by 3 maxima (Pl. II, Fig. 6), one of which occurs in the undermost section of the layer. Separated from this one by a marked minimum the absolute maximum of this species appears in sample no. 3; it is characterized by the steep rise of the lower part of the curve and by the gentle descent of its upper part towards the minimum above. The third maximum is discernible in the upper section of the deposit.

Pl. II, Fig. 7 illustrates the frequency of the *Pisidium* species; they can be divided into one group with high frequency and one with low. The former group consists of *P. nitidum*, *P. subtruncatum*, *P. obtusale*, and *P. milium*. All of these species, except *P. subtruncatum*, are already represented immediately above the *MLB*. *P. subtruncatum* was observed in considerable numbers as early as in sample no. 2. As to the remaining course of the frequency curve of this species, it shows considerable fluctuations in the lower half of the deposit with two maxima separated by a distinct minimum. In the upper part of the stratum the curve runs without great fluctuations and holds an inferior position in relation to the other frequency curves in the same diagram. *P. obtusale* reaches its highest value immediately above the *MLB*, whereupon its frequency curve takes an intermediate position until reaching a small maximum just below the *S II*. *P. milium*, chiefly represented by the variety

uniooides, has a low frequency in the bottom samples, but in sample 4 it suddenly reaches an important maximum, again, however, rapidly followed by a minimum simultaneously with the beginning of the momentary increase of the *P. subtruncatum* frequency curve just referred to. In the upper section of the deposit the frequency curve of *P. milium* is characterized by a quiet course; yet a slight maximum sets in just below the *S II*. The frequency curve of *P. nitidum* runs without greater fluctuations through the whole deposit, except for the section of samples nos. 4 and 5 where this species was temporarily forced to withdraw in favour of *P. milium* and *P. subtruncatum*. Like these species, *P. nitidum* reaches a maximum just below the *S II*; this maximum is considerably more pronounced than those of the other two species.

P. lilljeborgi, belonging to the group of *Pisidia* with low frequency, is distinguished by a distinct maximum just above the *MLB*, whereupon its frequency curve continues steadily as far as to the upper part of the deposit, where it changes into a slight maximum. This maximum takes place earlier than the upper maxima of the above-mentioned species. *P. hibernicum* shows an even and insignificant frequency in the lower part and a somewhat higher but less constant frequency in the upper. *P. henslowanum* was observed only in the upper part of the layer.

Of the two families with only a small number of shells, the Ancyliidae family is represented by a single species, viz. *Acroloxus lacustris* which makes its first appearance in sample no. 4 and then immediately reaches a maximum, whereupon the frequency successively decreases to reach zero just before the *S II*. The other family, Physidae, is, likewise, represented by a single species, viz. *Physa fontinalis*. Its earliest appearance coincides with that of the family Ancyliidae. In the next succeeding sample it was not observed, but thereafter its frequency increases steadily. *Physa* continued to occur close to the *S II*.

Other freshwater organisms. In samples nos. 1 and 2 ephippia of *Daphnia pulex*; in nos. 6 and 8 eggs of *Turbellaria rhabdocoela*; in nos. 1-9 statoblasts of *Cristatella* cf. *mucedo*; in nos. 6, 8, and 9 chitin of insects; and, finally, in nos. 1-6 and no. 8 fragments of fish skeletons.

Marine organisms. Remains of shells of *Mytilus edulis*, *Hydrobia* sp. (juv), and *Balanus* cf. *balanus* as well as foraminiferal shells (*Elphidium*) and entire shells of an ostracod (*Cythere lutea*) were observed. *Hydrobia* occur in sample no. 1, whereas *Cythere lutea* and *Balanus* are represented in samples 1-4 and fragments of *Mytilus* and shells of *Elphidium* in nos. 1-8.

Vegetation

Fruits and vegetative components from the evidently very abundant higher vegetation of the ancient lake have been preserved in large quantities. The frequency of the fruits which occur in greatest numbers is reproduced graphically in Pl. II, Fig. 8. Fruits of *Potamogeton* are the most numerous; their frequency is, however, rather varying. The dominating species are *P. obtusifolius* and *P. pectinatus*. A pronounced maximum of *Potamogeton* in the lower part of the stratum is chiefly formed by both these species. *P. pectinatus* reaches its maximum first. In the upper part of the layer the course of the total curve of *Potamogeton* is almost exclusively influenced by the *P. obtusifolius* curve. Just below the *S II* the curve attains a smaller maximum. — The seeds of *P. pectinatus*, having a typical appearance, are rather small; the average length amounts to 3 mm.

Pl. II, Fig. 8 also shows the frequencies of the genera *Scirpus* and *Carex*. Like *Potamogeton*, they attain maxima in the lower section as well as in the uppermost part of the stratum. The upper maximum is the most important.

The following table is a complete list of the species observed:

	1	2	3	4	6	7	8	9
<i>Potamogeton obtusifolius</i>	12	24	26	64	13	14	61	19
» <i>pectinatus</i>	—	1	72	69	1	1	—	—
» <i>filiformis</i>	2	—	—	3	—	1	2	4
» <i>natans</i>	—	—	3	—	—	—	—	—
» <i>perfoliatus</i>	—	1	—	—	—	—	—	—
<i>Scirpus lacustris</i>	2	1	5	1	1	3	—	23
» <i>maritimus</i>	—	—	2	—	—	—	—	—
» sp.	—	—	2	—	—	—	—	—
<i>Carex</i> spp.	4	1	2	1	1	—	7	12
<i>Betula</i> sp.	—	—	—	—	—	1	—	—
<i>Nymphaea alba</i>	—	—	2	1	—	1	—	—
<i>Myriophyllum spicatum</i>	—	—	2	—	—	—	1	—
<i>Arctostaphylos uva ursi</i>	—	—	2	—	—	—	—	—
<i>Menyanthes trifoliata</i>	—	—	—	—	—	—	—	2

Oospores of Charophytes occur in all the samples, though with varying frequency. They are rare in nos. 1-3, but they appear suddenly in great numbers in the fourth sample. In no. 5, again, they are rare; in the following four samples, however, they are numerous — in the seventh and ninth very numerous. The uppermost sample contains only a small number of oospores. As a rule, the oospores appearing in the samples with an inferior frequency are not covered with calcium carbonate, whereas those occurring in samples with a high frequency are freely encrusted. Exceptions from this are the oospores in no. 9 which are non-encrusted, and those occurring in no. 2 which show signs of having been covered with calcium carbonate to a rather great extent.

Age

Pollen diagram Pl. I, Fig. 3.

The *MLB* was formed somewhat after the *BM^{int.}*, and the sedimentation of the shell-bearing freshwater layer was finished at about the *BM^{sup.}* and the *C⁰*; the *A⁰* appears in the upper part of the non-calcareous coarse necron mud.

The shell-bearing layer was thus accumulated during the transition from the Finiglacial to the Postglacial period.

Stuvängen

Kville parish: from the Rabbalshede railway station S 82° W, 3.2 km; soil surface 65 m above the sea.

The locality is identical with the peat soil no. 49 (v. POST 1923, map no. 51). It has also been described by HESSLAND 1946.

The shell-bearing sediment consists of calcareous necron mud; it is included in the following sequence of strata:

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1. Deciduous fen-wood peat 2.2 m
2. Coarse non-calcareous necron mud 0.2 »
3. Calcareous necron mud 0.2 »
4. Lagoon clay 0.02 »
5. Shell-bearing marine blue clay.

The freshwater calcium carbonate may originate from the shell-bearing marine clay, and also from marine shell beds lying somewhat NE of the freshwater deposit. Five samples were taken up with a can-auger.

Weights:

Sample no. I	66.5 g
» » II	74.5 »
» » III	18.0 »
» » IV	19.0 »
» » V	48.0 »

The percentage distribution of phytogene and minerogene particles and of calcium carbonate was as follows:

	Phyt. comp.	Min. comp.	Calcium carbonate
Sample no. I	21	35	44
» » II	4	72	24
» » III	10	62	28
» » IV	21	31	48
» » V	2	81	17

Fauna

Ostracods. Shells of ostracods occur in all the samples with the exception of no. I.

	II	III	IV	V
<i>Pionocypris vidua</i>	6	—	—	—
<i>Candona</i> sp.....	22	12	11	5

Molluscs. The frequency of shells was:

Sample no. I	270
» » II	290
» » III	580
» » IV	540
» » V	57

The percentage distribution of the species was:

	I	II	III	IV	V
<i>Lymnaea ovata</i>	25	19	28	22	14
<i>Stagnicola palustris</i>	—	+	—	—	—
<i>Gyraulus arcticus</i>	43	56	62	61	46
<i>Armiger crista</i>	7	6	6	4	22
<i>Hippeuthis complanatus</i>	—	1	1	—	—
<i>Valvata cristata</i>	4	4	—	5	11
<i>Sphaerium corneum</i>	—	1	—	1	—
<i>Pisidium</i> spp.	21	13	3	7	7
» <i>nitidum</i>	(7)	(1)	—	(2)	—
» <i>milium</i>	(6)	(9)	(2)	(2)	—
» <i>lilljeborgi</i>	(1)	—	—	—	—
» <i>hibernicum</i>	(2)	—	(1)	(3)	—
» <i>subtruncatum</i>	(5)	(2)	—	—	(7)
» sp.	—	(1)	—	—	—

It appears that *Gyraulus arcticus* is the most abundant species. *Lymnaea ovata* also reaches a high frequency. *Armiger crista* (f. *typica* and f. *nautilea*), *Valvata cristata*, and *Pisidium milium* occur in rather considerable numbers.

Other freshwater organisms. One ephippium of *Daphnia pulex* was observed in sample no. I; one cocoon of *Dendrocoelum* cf. *lactum* in no. II; statoblasts of *Cristatella* cf. *mucedo* in no. IV; chitin of insects in nos. I, II, and V; and a fish vertebra in no. I.

Marine organisms. Foraminiferal shells referable to species of the genus *Elphidium* occur very numerously in no. V. In the same sample appeared also some fragments of *Balanus* and a single fragment of *Littorina littorea*. Remains of *Mytilus* shells were observed in nos. I, III, and V.

Vegetation

Fruits and seeds of the following species were found:

	I	II	III	IV	V
<i>Potamogeton pectinatus</i>	18	16	11	6	—
» <i>praelongus</i>	—	1	—	—	—
» <i>natans</i>	3	4	—	11	—
» <i>trichoides</i>	—	—	—	6	—
» sp.	—	—	—	—	2
<i>Ruppia rostellata</i>	1	4	17	—	4
» <i>spiralis</i>	—	3	5	—	—
» sp.	—	—	5	—	—
<i>Najas marina</i>	3	1	—	—	—
<i>Scirpus lacustris</i>	1	—	—	—	—
» sp.	—	—	5	—	—
<i>Carex</i> spp.	1	2	—	—	—
<i>Juncus</i> sp.	—	1	—	—	—
<i>Nymphaea alba</i>	1	—	—	—	—
<i>Ceratophyllum submersum</i> ..	3	1	—	—	—
<i>Hypericum</i> sp.	—	1	—	—	—

Oospores of Charophytes were found in all samples. They are not encrusted with calcium carbonate.

Age

Pollen diagram Pl. I, Fig. 8.

The exact position of the $BM^{sup.}$ is not perfectly known; it may be represented by the *Betula* maximum just at the MLB where also the C^0 appears; the $BM^{inj.}$ seems to occur at a lower level. The shell-bearing layer corresponds to the earliest third of the great Boreal hazel maximum. The A^0 appears far higher up, viz. in the fen peat.

The shell-bearing stratum was formed during a very early part of the Postglacial period.

Hjelpedsten

Kville parish: from the Rabbalshede railway station S 72° W, 3.1 km; soil surface 68 m above the sea.

The locality is identical with the peat soil no. 48 (v. Post 1923, map no. 51).

Calcareous sediments occur within a small area in the centre of the mire. The sequence of strata consists of:

1. Deciduous fen-wood peat 175–250 cm
2. Coarse non-calcareous necron mud 45 »
3. Calcareous necron mud and lake chalk 30 »
4. Greyish-yellow necron mud 10 »
5. Shell-bearing marine blue clay.

The calcium carbonate of the freshwater stratum is certainly derived from shells in the marine clay, and also from a very important shell bed lying close by.

Samples were taken up with a can-auger at two points within the calcareous area. From one of these points 2 samples were analysed (nos. I and II), while from the other point 7 samples were investigated (nos. 1–7).

The quantities analysed were:

Sample no. I	57	g
» » II	70	»
» » 1	75	»
» » 2	25	»
» » 3	19	»
» » 4	113	»
» » 5	24.5	»
» » 6	19	»
» » 7	27	»

The percentage frequency of minerogene and phytogene particles and of calcium carbonate was:

	Phyt. comp.	Min. comp.	Calcium carbonate
Sample no. I	8	16	76
» » II	7	10	83
» » 1	5	4	91
» » 2	8	14	78
» » 3	15	20	65
» » 4	7	10	83
» » 5	7	8	85
» » 6	13	22	65
» » 7	13	16	71

Fauna

For faunistical purpose five samples were investigated quantitatively (II, 1, 3, 5, 6, and 7); the others were examined qualitatively.

Ostracods. Shells of ostracods were found in all samples, except 3, 6, and 7. The following species were observed:

	I	II	1	2	4	5
<i>Pionocypris vidua</i>	2	—	—	4	—	—
<i>Candona</i> sp.....	8	4	11	4	3	48
<i>Cyprideis littoralis</i>	2	—	—	4	—	—
<i>Cytheridea papillosa</i>	2	—	4	—	—	—

Cyprideis littoralis is a brackish water species, *Cytheridea papillosa* a marine.

Molluscs. Frequency of shells:

Sample no. II	560
» » 1	530
» » 3	1080
» » 5	2700
» » 6	80
» » 7	330

The percentage distribution of the mollusc species:

	II	1	3	5	6	7
<i>Succinea</i> sp.....	2	2	5	2	—	6
<i>Lymnaea ovata</i>	20	22	21	18	33	23
» <i>auricularia</i>	+	+	—	1	—	1
» sp.....	1	1	—	—	—	—
<i>Physa fontinalis</i>	+	—	—	—	—	—
<i>Gyraulus arcticus</i>	3	1	1	4	—	13
<i>Armiger crista</i>	1	1	1	1	—	—
<i>Hippeuthis complanatus</i>	5	6	2	4	—	1
<i>Acroloxus lacustris</i>	—	+	—	1	—	—
<i>Valvata cristata</i>	15	14	11	13	20	2
<i>Sphaerium corneum</i>	+	1	2	+	—	—
<i>Pisidium</i> spp.....	53	51	57	56	47	54
» <i>nitidum</i>	(26)	(29)	(25)	(27)	(33)	(28)
» <i>milium</i>	(16)	(14)	(25)	(16)	(7)	(23)
» <i>lilljeborgi</i>	—	—	(+)	(2)	—	—
» <i>hibernicum</i>	(1)	(1)	(1)	(1)	—	—
» <i>obtusale</i>	(1)	(1)	(3)	(2)	—	—
» <i>subtruncatum</i>	(3)	(4)	(3)	(7)	(7)	(1)
» sp.....	(6)	(3)	(+)	(1)	—	(2)

The table shows that the frequency of each species is rather equal in the different samples. *Lymnaea ovata*, *Valvata cristata*, *Pisidium nitidum*, and *P. milium* are predominant. The occurrence of the terrestrial pulmonate gastropod *Succinea* sug-

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gests that the calcareous sediment was deposited rather near the shore, since this gastropod lives especially on the shore vegetation.

Other freshwater organisms. Cocoons of *Dendrocoelum* cf. *lacteum* were observed in samples II and 7; eggs of rhabdocoels in no. 7; statoblasts of *Cristatella* cf. *mucedo* in nos. I, II, 2, 4, 5, and 6; chitin of insects in nos. II, 1, 3, 5, 6, and 7; and remains of fish skeletons in nos. I, II, and 6.

Marine organisms. A fragment of a shell of *Mytilus* was found in no. II and shells of *Cytheridea papillosa* in nos. I and 1.

Vegetation

Only small quantities of vegetative plant components have been preserved in the calcareous sediment. Fruits or seeds of the following species were observed:

	I	II	1	2	3	4	5	6	7
<i>Pinus silvestris</i>	—	—	1	—	—	—	—	—	—
<i>Potamogeton natans</i>	5	7	4	—	21	9	8	10	4
» <i>gramineus</i> ...	—	1	—	—	—	—	—	—	—
» <i>trichoides</i> ...	—	1	—	—	—	—	—	5	—
» <i>pectinatus</i> ...	—	—	—	—	5	—	4	—	—
<i>Ruppia rostellata</i>	—	1	—	—	—	—	—	—	—
<i>Najas marina</i>	16	13	6	20	47	14	4	20	22
<i>Scirpus maritimus</i>	—	—	—	—	—	—	—	—	4
? <i>Rhynchospora alba</i>	—	—	1	—	—	—	—	—	—
<i>Carex</i> cf. <i>pulchella</i>	—	—	1	—	—	—	—	—	—
» spp.....	—	3	3	—	10	6	4	5	7
<i>Betula</i> cf. <i>verrucosa</i>	—	—	—	—	—	—	—	—	7
<i>Nymphaea alba</i>	—	3	—	—	—	6	—	—	11
<i>Ranunculus</i> spp.....	—	1	—	—	—	—	—	—	7
<i>Lycopus europaeus</i>	—	—	1	—	—	1	—	—	—

Some fruits of *Ceratophyllum submersum* L. were observed in the samples taken for pollen analysis.

Oospores of Charophytes occur in all samples; they are not encrusted with calcium carbonate.

Age

Pollen diagram Pl. I, Fig. 9.

The marino-limnic boundary is obviously situated somewhat above the *BM*^{inf.}. The *C*⁰ and possibly the *BM*^{sup.} appear slightly below this boundary; the shell-bearing layer corresponds to the earlier third of the great Boreal hazel maximum. The *A*⁰ occurs in the lower part of the fen peat, and the *T*⁰ somewhat higher.

The shell-bearing stratum was formed during a very early part of the Postglacial period.

Korndalen

Tanum parish: from the Orrekläpp railway station S 72° E, 4.5 km; soil surface 71 m above the sea.

Stratal sequence:

1. Peat and coarse non-calcareous necron mud..... 115 cm
2. Calcareous necron mud (greyish-brown)..... 5 »
3. Calcareous necron mud (greyish-blue)..... 12 »
4. Sandy, marine blue clay with shells.

The freshwater calcium carbonate originates certainly from the underlaying marine clay and possibly from rather important shell-bearing marine deposits situated in the glen SW of the freshwater sediments.

For analytical purpose three samples were taken up with a can-auger.

Weights:

Sample no. I	197 g
» » II	349 »
» » III	154 »

The percentage content of phytogene and minerogene particles and of calcium carbonate appears from the table below:

	Phyt. comp.	Min. comp.	Calcium carbonate
Sample no. I	95	3	2
» » II	96	1	3
» » III	96	2	2

Fauna

Samples II and III were analysed quantitatively, no. I, on the other hand, only qualitatively.

Ostracods. No shells of ostracods were observed.

Molluscs. Frequency of shells:

Sample no. II	90
» » III	120

The percentage distribution of the species was:

	II	III
<i>Lymnaea ovata</i>	24	33
<i>Gyraulus arcticus</i>	61	40
» <i>albus</i>	+	+
<i>Armiger crista</i>	5	18
<i>Hippeuthis complanatus</i>	1	2
<i>Sphaerium corneum</i>	—	2
<i>Pisidium</i> spp.	9	5
» <i>nitidum</i>	(7)	(3)
» <i>milium</i>	(2)	(2)

Other freshwater organisms. A wing of an insect was observed in no. I and fragments of fish skeletons in nos. II and III.

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Marine organisms. Fragments of shells referable to *Mytilus* and *Balanus* occur in samples I and II. Entire shells of *Hydrobia ulvae* are rather abundant in all samples. *Rissoa parva* and a single shell of *Littorina littorea* juv. were observed in no. III, and fragments of *Astarte borealis* and *Saxicava arctica* in no. II. In no. II there occur also shells of *Nonion labradoricum* and *Elphidium* spp.

Vegetation

Vegetative components of the plants in the ancient lake have been embedded in the shell-bearing layer only in small quantities, but fruits and seeds are abundant as appears from the following table:

	I	II	III
<i>Potamogeton gramineus</i>	17	30	32
» <i>natans</i>	18	29	30
» <i>pectinatus</i>	—	—	2
» sp.	1	—	—
<i>Alisma plantago-aquatica</i>	—	1	—
<i>Ruppia rostellata</i>	—	1	—
<i>Zannichellia repens</i>	—	2	—
<i>Carex canescens</i>	—	1	1
» sp.	5	1	6
<i>Polygonum</i> cf. <i>persicaria</i>	—	1	—
» cf. <i>hydropiper</i>	1	—	—
? <i>Montia lamprosperma</i>	—	—	1
<i>Atriplex</i> spp.	—	2	—
<i>Ranunculus</i> cf. <i>peltatus</i>	1	—	1
<i>Myriophyllum spicatum</i>	2	—	1
<i>Hippuris vulgaris</i>	—	1	2
<i>Naumburgia thyrsiflora</i>	—	1	—
<i>Menyanthes trifoliata</i>	—	—	1

A gramineal seed and a leaf of *Salix* plus some few indeterminate seeds were observed in no. II.

Oospores of Charophytes are numerous. They have no covering of calcium carbonate.

Age

Pollen diagram Pl. I, Fig. 11.

The C^0 is situated in the shell-bearing layer. The A^0 appears in the lower part of the peat. The T^0 occurs somewhat higher in the peat. The *Betula* maximum appearing contemporaneously with the *Corylus* maximum may not be identifiable with the BM^{sup} , which may have been developed earlier.

The shell-bearing stratum was obviously formed during an early part of the Post-glacial period.

Fossane

Kville parish: from the Rabbalshede railway station N 15° E, 2.1 km; soil surface 77 m above the sea.

The calcareous freshwater stratum (10–20 cm thick) is underlain by a stiff and

greyish-yellow clay, free from shells (about 30 cm thick); this is probably a freshwater layer. Below this one is shell-bearing marine clay.

The freshwater calcium carbonate cannot have been derived from the stiff clay. The sources of calcium carbonate must be traced among the shell-bearing marine clays in the vicinity.

For analyses a sediment pillar was divided into 3 samples:

Sample no.	Height	Weight
3 (top)	7 cm	53 g
2 (middle part)	7 »	59 »
1 (bottom)	6 »	42 »

The percentage of calcium carbonate and the proportions of phytogene and minerogene particles are illustrated in Pl. III, Fig. 13.

Fauna

The frequency of the shells of ostracods and molluscs is reproduced in Pl. III, Fig. 14.

Ostracods. No shells of ostracods were found in sample 1, but they appear abundantly in the others, especially in no. 3. The following species were found:

	2	3
<i>Iliocypris gibba</i>	—	13
<i>Iliocyprilla bradyi</i>	—	14
<i>Herpetocypris reptans</i>	5	—
<i>Heterocypris incongruens</i>	29	79
<i>Pionocypris vidua</i>	52	85
<i>Candona</i> sp.	340	1 260
<i>Darwinula</i> sp.	—	1

Molluscs. The frequency of the most numerous families is shown graphically in Pl. III, Fig. 15. From this diagram it appears that the families Lymnaeidae and Sphaeriidae reach their highest frequency as early as immediately above the *MLB*. The family Planorbidae, on the contrary, has a very pronounced maximum just below the *S II*. The family Valvatidae takes an intermediate position.

The percentage frequency of the less abundant families has not been illustrated graphically; instead, it is tabulated below:

	1	2	3
Physidae	—	—	1
Ancylidae	—	+	1

These families are represented by one species each, viz. *Physa fontinalis* and *Acroloxus lacustris* respectively. This is also the case as regards Valvatidae, which is represented by *Valvata cristata*. The family Planorbidae, on the other hand, is represented by 4 species: *Gyraulus arcticus*, *Gyraulus albus*, *Armiger crista* (f. *typica*

and *f. nautila*), and *Hippeuthis complanatus*. *Gyraulus albus* was found only in sample 2; the frequency is low ($< 1/2$ per cent). The distribution of the three other species is shown in Pl. III, Fig. 16. This diagram illustrates that *Gyraulus arcticus* and *Hippeuthis complanatus* reach their greatest abundance in the bottom section of the layer; their frequency decreases successively upwards. The course of the frequency curve of *Armiger crista* is quite inverse.

The family Sphaeriidae is represented by *Sphaerium corneum* and species belonging to the genus *Pisidium*. *Sphaerium* dominates in the lower part of the stratum and *Pisidium* in the upper (Pl. III, Fig. 17). A list of the *Pisidium* species is given below (percentage frequency of the total shell number).

	1	2	3
<i>Pisidium nitidum</i>	4	+	+
» <i>milium</i>	+	2	+
» <i>lilljeborgi</i>	—	+	+
» <i>obtusale</i>	+	+	—

Other freshwater organisms. Statoblasts of *Cristatella* cf. *mucedo* occur rarely in samples 2 and 3. Fish remains were found in all samples.

Marine organisms. No marine organisms were observed in the freshwater sediment.

Vegetation

Remnants of plants increase in frequency towards the top of the layer. Vegetative components are rather abundant in samples 2 and 3. On the other hand, seeds are fairly rare; moreover, they are macerated to such an extent that only the cuticle within the harder external wall remains.

	1	2	3
<i>Potamogeton</i> sp.....	14	2	8
<i>Nymphaea alba</i>	10	2	—

Some pieces of coniferous bark were observed in sample 1 and a needle of pine in no. 3.

Oospores of Charophytes are common in samples 1 and 2, but rare in no. 3. Some transparent bodies of chitin, strongly reminiscent of Characaeal oospores in size and shape, were observed in no. 1.

Age

Pollen diagram Pl. I, Fig. 10.

The accumulation of the shell-bearing freshwater layer began contemporaneously with the great rise of the *Alnus* curve. The T^0 appears somewhat higher; the C^0 occurs lower in the underlying clay and the *Betula maxima* at a further lower level.

This shell-bearing stratum was formed during a short section of an early part of the Postglacial period but somewhat later than the other Postglacial deposits described in this paper, being the only one entirely later than the A^0 .

Survey of the constituents of the shell-bearing sediments

Calcium carbonate, and minerogene and phytogene components

From the descriptions of the localities it appears that the composition of the shell-bearing deposits varies both from locality to locality and within different horizons of the same stratum. However, it is characteristic of all the strata that the sediment is calcareous which shows that the percentage of calcium carbonate in the water must have been high. This is an important condition for a rich occurrence of shell-bearing organisms (cf. BOYCOTT 1936, p. 146 and HUBENDICK 1947, p. 494). A calcareous sediment, on the other hand, is suitable for preservation of shells. The overlying coarse non-calcareous necron mud is not suitable in this respect. Shell-bearing organisms have probably occurred in the lakes when this necron mud accumulated but no shells have been preserved. They may have been dissolved by acidic decomposition products of the great quantities of decaying plasma.

In some of the samples the calcium carbonate content amounts only to a few per cent; in others, again, it closely approaches 100 per cent. As a rule, the percentage of calcium carbonate is highest in the middle part of the shell-bearing strata. In the lower part, the percentage of minerogene particles generally exceeds the percentage of calcium carbonate. The frequency of minerogene particles mostly shows a continual decrease from the underlying marine sediment, which is chiefly blue clay. Clay particles thus form the main part of the sediment which was brought to the ancient lakes during the first period after their separation from the sea. The clay particles must have been eroded from the surrounding ground just emerged from the sea; a great part of these particles certainly originates from the very shore of the ancient lakes. In this way, marine shells became exposed and dissolved, whereby the water of the ancient lakes successively obtained a higher content of calcium carbonate. Calcium carbonate was also often supplied from marine shell beds in the vicinity. The increase of accessible parent substances of calcium carbonate by the exposure and, on the contrary, the decrease of the minerogene parent substances had the result that, in time, the supply of calcium carbonate surpassed that of minerogene particles.

The calcium carbonate in the water was partly consumed by shell-bearing organisms and organisms incorporating calcium carbonate in their tissues. As the supply, however, was so abundant that organisms could not consume all the calcium carbonate, the rest was precipitated to a great extent. The precipitates constitute the main part of the calcium carbonate in the sediment. It must have been formed when the easily soluble bicarbonate lost carbon dioxide. This may have been realized in an abiogene way or by assimilation of carbon dioxide by plants. Moreover, certain organisms have special ability for precipitation of calcium carbonate, such as many blue-green algae among the cryptogams, and many phanerogams, e. g. some *Potamogeton* and *Ranunculus* species, *Nymphaea*, *Ceratophyllum*, and *Myriophyllum*. Crusts of calcium carbonate, such as formed by phanerogams, easily crumble to minute pieces. It is generally difficult to state the origin of such pieces. They constitute an important component of the calcareous silt of the modern Gotland freshwater sediments (LUNDQVIST 1940, p. 58).

Vegetation also played an important rôle for shell-bearing organisms in other respects. The macro-vegetation served as substratum for several gastropoda, and algae and phytogene detritus were eaten by the phytophagans and detritophagans.

Parts of the fine detritus originate from the micro-vegetation and parts from the vascular plants. There is a certain conformity between the percentage of phytogene fine-particles and larger vegetative remains of the macro-vegetation. As a rule, the percentage of phytogene particles increases continually towards the *S II*.

In sum, in the typical case, the shell-bearing freshwater beds are characterized by the fact that minerogene fine-particles dominate the bottom part, calcareous sediments the middle one, and phytogene constituents the upper part. Phytogene substances grew especially dominating during the last stage of the lakes when vegetation had become so very abundant that a coarse necron mud was formed.

It may be added that the amount of minerogene fine-particles generally increases just towards the *S II*, though in smaller degree than the phytogene components. This is certainly due to diminished supply of calcium carbonate but it may also be due to the fact that aeolian sediments were caught by the vegetation, which, at that stage in the development of the ancient lake, had become more emerse than earlier.

Distribution of mollusc shells

In most cases the highest frequency of mollusc shells per 100 g of sediment appears in the upper part of the shell-bearing layer — not unusually just below the *S II* (Pl. III, Figs. 2, 8, and 14). It is possible that the molluscs in the ancient ponds actually were more abundant during this stage than during the previous ones; but it may also happen that this was not the case. There is reason to assume that the supply of calcium carbonate — the most important component of the sediment — had diminished during this later stage. Since the shell frequency is referable to 100 g of sediment, a status quo or even a decrease of the molluscan number can look like an increase of frequency if the velocity of calcium carbonate precipitation had diminished. Pl. II, Fig. 3 presents a total curve which is remarkable in showing no fewer than 4 maxima separated by pronounced minima. The absolute maximum falls somewhat below the middle of the shell-bearing stratum and a slight maximum appears just below the *S II*.

The mollusc families, genera, and species may show some conformity as to frequency in vertical series of samples. However, there exists no far-reaching correspondence in this respect, as will appear from the following survey.

The most abundant families are Lymnaeidae (on an average 20 per cent of the shells), Planorbidae (30 per cent), Valvatidae (11 per cent), and Sphaeriidae (39 per cent). The families Succineidae, Physidae, and Ancyliidae are represented with < 1 per cent. The high frequency of shells just below the *S II* is most often caused by Valvatidae and Sphaeriidae (Pl. II, Fig. 4 and Pl. III, Figs. 3 and 9). In one case, Planorbidae has a pronounced maximum in the upper part of the shell-bearing layer (Pl. III, Fig. 15). Lymnaeidae, Planorbidae, and Sphaeriidae form the great maximum in the middle of a layer as illustrated in Pl. II, Figs. 3 and 4. Striking in this deposit is the fact that Valvatidae reaches one slight maximum immediately above the *S I* and another very important just below the *S II* but is nearly absent in the intervening part of the stratum. In the bottommost part of the shell-bearing layers Lymnaeidae, Sphaeriidae, and/or Planorbidae are the most abundant families (Pl. II, Fig. 4 and Pl. III, Figs. 9 and 15); in one locality, Valvatidae has the highest frequency among the families represented in this horizon (Pl. III, Fig. 3).

The family Lymnaeidae is represented by *Lymnaea (Radix) ovata* (DRAPARNAUD), *L. auricularia* (L.), and *Stagnicola palustris* (MÜLLER). *Lymnaea ovata* occurs as *f. typica* but also as the varieties *peregra* MÜLLER and *lagotis* (SCHRANK) (cf. p. 120). It was found in all deposits examined, with a mean frequency of 20 per cent of the shells, i. e. it is one of the most abundant species. *L. ovata* occurs in all samples and has the most equable frequency. *L. auricularia*, on the other hand, is represented in 4 localities only; the mean frequency in relation to all shells comes to < 1 per cent. The mean frequency of *Stagnicola palustris* is also < 1 per cent. This species was found in 3 localities; it constitutes a rather conspicuous component of the mollusc fauna in one of them (Rabbalshede).

The family Planorbidae is represented by *Gyraulus arcticus* BECK, *G. albus* MÜLLER, *Armiger crista* (L.), and *Hippeuthis complanatus* DRAPARNAUD [*Planorbis fontanus* (LIGHTFOOT)]. *Gyraulus arcticus* is one of the most abundant species with an average frequency of 24 per cent of the shells. It was found in great numbers in every deposit with the exception of Klingseröd II, where the frequency is remarkably low (on an average < 1 per cent of the shells). Maxima in the frequency of *G. arcticus* were observed both in the lower half of the layers (Pl. II, Fig. 5 and Pl. III, Fig. 16) and the middle part (Branstaby); as appears from Pl. III, Fig. 11, very high frequency data may further occur in the upper part of the layer. The fact is noteworthy that this species, which is considered to be a northern species today, is abundant in the Fossane deposit which was accumulated somewhat after the A^0 , thus in the middle part of the Ancyclus period (on an average 30 per cent of the shells). Contrary to *G. arcticus*, *G. albus* occurs in small numbers (< 1 per cent); it was observed in 6 localities. The highest frequency was found in the middle of the layers (Klingseröd II and Fossane) and the top (Branstaby). The species was also observed in the bottom part. *Armiger crista* is represented by the main type (*Armiger crista cristata* [DRAPARNAUD]) and the variety *nautila* (L.); they occur together. The species was found in all deposits with a mean frequency of 12 per cent of the shells. In several cases maxima appear in the upper part of the shell-bearing stratum, even immediately below the *S II* (Pl. II, Fig. 5 and Pl. III, Figs. 5 and 16). In the same deposits another maximum may occur just above the *S I*. Sometimes, a maximum falls in the middle of the layer (e. g. Rabbalshede). The frequency of *Hippeuthis complanatus* is generally low: on an average about 1 per cent of the shells. It was observed in all localities except two. The highest frequency was mostly found in the upper part of the layer (Pl. II, Fig. 5, Pl. III, Fig. 11, and Branstaby); the maximum can also fall in the middle (Pl. III, Fig. 5) and in the bottom part (Pl. III, Fig. 16).

The family Valvatidae is represented by *Valvata cristata* MÜLLER and *V. piscinalis* MÜLLER. The mean frequency of *V. cristata* is 11 per cent; the species was found in 8 localities. Maxima occur both in the upper and the lower part of a deposit (Pl. II, Fig. 4 and Pl. III, Fig. 3). The highest frequency can also be attained either in the upper or the middle part (cf. Pl. III, Figs. 9 and 15). *V. piscinalis* was only observed in 4 localities (average frequency about 2 per cent of all shells). In two localities this species was rather common (Branstaby and Klingseröd II, Pl. III, Fig. 4); in the latter locality its frequency conforms mainly with that of *V. cristata*.

The family Sphaeriidae is represented by *Sphaerium corneum* (L.) and seven species of the genus *Pisidium*. *Sphaerium* was found in all deposits examined, except two. The frequency is generally low; on an average about 1 per cent of the shells. In one locality it has a pronounced maximum in the bottom part of the

layer (Pl. III, Fig. 17). This species may also be represented in the middle of the layers and close to the *S II*. Among the *Pisidia*, *P. nitidum* JENYNS and *P. milium* HELD are the most abundant. On an average, the first species, found in all deposits, is represented by 11 per cent and the latter, absent in one locality, by 9 per cent of the shells. They are not unusually very frequent both in the top and in the bottom section of the layers. *P. nitidum*, especially, seems to have the capacity of enduring, without difficulty, the bad conditions which appear towards the disappearance of lakes. *P. milium* is often represented by the variety *unioides* WESTERLUND. The remaining species of *Pisidium* occur with mean frequencies varying between < 1 and 3 per cent of the shells. *P. obtusale* PFEIFFER was observed in all deposits except two; the average frequency is about 2 per cent of the shells. The curve of frequency of this species may occasionally have a similar course with those of *P. nitidum* and *P. milium* (Pl. II, Fig. 7). *P. subtruncatum* MALM is represented in 8 localities with a mean frequency of about 1 per cent. The frequency curve of this species runs in a way somewhat different from those of the *Pisidia* just mentioned. This also applies to *P. hibernicum* WESTERLUND. Its maximum occurs either in the bottom part (Pl. III, Fig. 6) or in the upper one (Pl. II, Fig. 7); the frequency may also be about the same throughout the stratum (Pl. III, Fig. 10). It was observed in 8 localities with an average frequency of 3 per cent of all shells. *P. lilljeborgi* CLESSIN was found in 9 localities; it shows a low frequency (1 per cent in average). This species appears with a maximum frequency in the bottommost part of the layers (Pl. II, Fig. 7 and Pl. III, Fig. 6); in others, again, it occurs only in the upper half (Fossane [p. 140] and Pl. III, Fig. 10). *P. henslowianum* SHEPPARD, appearing in two localities with a mean frequency < 1 per cent of the shells, was observed only in the upper half of the strata (Pl. II, Fig. 7 and Pl. III, Fig. 6).

The families Succineidae, Physidae, and Ancyridae are represented by one species each; *Succinea* cf. *putris* L., *Physa fontinalis* (L.), and *Acroloxus lacustris* (L.), respectively. They were observed in 3, 7, and 8 localities resp. The mean frequency in relation to all shells is < 1 per cent. *Physa* and *Acroloxus* generally occur in the middle and upper part of the shell-bearing strata.

We shall now investigate whether the representation and vertical distribution of the molluscs are consequences of climate. If this factor was of main importance, this would have been demonstrated in such a way that the species would have occurred exclusively or with remarkably high frequencies in periods with a climate corresponding to that of their present habitats. For this purpose I have collected in the table on p. 145 the average frequency of the species in the different localities. (The oldest locality to the left and the latest to the right; the intermediate arranged between them.)

Most of the species are very eurythermal. Their distribution as shown in the table is certainly not a consequence of climate. Differences in their frequency among the deposits, and fluctuations in their vertical representation within the same layer must have been caused by local conditions. Some other species have a southern range, such as *Gyraulus albus*, *Hippeuthis complanatus*, and *Acroloxus lacustris*. They do not occur in the Flöghult locality but appear in the oldest parts of the next younger group of localities. Their absence in the Flöghult samples may be a consequence of climate, but this can scarcely be proved owing to the smallness of the samples. The different frequency of the species in the remaining localities is certainly due to accidental circumstances and local conditions.

The ability of dispersal and some ecological demands of the species represented

may also be briefly discussed on the basis of the present material. The first question may be elucidated by examining whether some species have the capacity of rapid occupation of lakes just separated from the sea. The table on p. 146 gives the frequency of the species observed immediately above the *MLB* (the frequency of the species which occur immediately below the *SII* are printed in italics; these data will be discussed later). It appears that only 3 of the 20 species observed were not found immediately above the *MLB* in any deposit: *Succinea* cf. *putris*, *Lymnaea auricularia*, and *Pisidium henslowanum*. The other species are represented in the following way: one locality: *Stagnicola palustris* and *Physa fontinalis*; two localities: *Gyraulus albus* and *Acroloxus lacustris*; three localities: *Hippeuthis complanatus*, *Valvata piscinalis*, *Sphaerium corneum*, and *Pisidium lilljeborgi*; four localities: *Pisidium subtruncatum*; five localities: *Valvata cristata* and *Pisidium hibernicum*; six or all localities: *Lymnaea ovata*, *Gyraulus arcticus*, *Armiger crista*, *Pisidium nitidum*, *P. obtusale*, and *P. milium*.

The last-mentioned group obviously consists of species with especially great ability for occupying new lakes. *Lymnaea ovata* may be mentioned first among them, not only for the reason that it shows the highest average frequency just above the *MLB* but also on account of its rather uniform abundance in this horizon.

	Flöghult	Klingseröd II	Askeröd	Kålstad	Rabballshede	Branstaby	Klingseröd I	Stuvången	Hjelpedsten	Korndalen	Fossane	Average frequency
<i>Succinea</i> cf. <i>putris</i>	4	—	+	—	—	—	—	—	3	—	—	+
<i>Lymnaea ovata</i>	10	6	2	21	36	29	13	22	23	29	29	20
» <i>auricularia</i>	2	—	+	+	—	—	—	—	+	—	—	+
<i>Stagnicola palustris</i>	3	—	—	—	5	—	—	+	—	—	—	+
<i>Physa fontinalis</i>	—	1	—	+	—	+	1	—	+	—	+	+
<i>Gyraulus arcticus</i>	66	+	32	3	27	22	20	54	4	50	13	24
» <i>albus</i>	—	2	+	—	+	+	—	—	—	+	—	+
<i>Armiger crista</i>	1	23	28	1	2	13	16	9	1	12	38	12
<i>Hippeuthis complanatus</i>	—	4	3	+	—	+	1	—	3	+	1	1
<i>Acroloxus lacustris</i>	—	1	2	+	—	+	1	—	+	+	1	+
<i>Valvata cristata</i>	—	51	10	6	—	11	6	5	13	—	5	11
» <i>piscinalis</i>	—	9	+	—	—	6	+	—	—	—	—	2
<i>Sphaerium corneum</i>	—	+	+	+	+	2	3	+	+	1	10	1
<i>Pisidium nitidum</i>	12	2	5	25	19	7	9	2	28	5	2	11
» <i>lilljeborgi</i>	—	+	2	2	1	1	2	+	+	—	+	1
» <i>subtruncatum</i>	—	+	1	6	2	1	7	3	4	—	—	3
» <i>obtusale</i>	2	1	9	+	2	1	8	—	1	—	+	2
» <i>hibernicum</i>	—	+	1	6	1	+	3	1	1	—	—	1
» <i>milium</i>	—	1	6	30	5	7	8	4	17	2	1	9
» <i>henslowanum</i>	—	+	—	—	—	—	1	—	—	—	—	+

The notion "ability of dispersal" is complex; several factors are of importance for the spread of lacustrine organisms. In the first place, the rapid occupation of new lakes and ponds is favoured by a high frequency of the species in the waters of the surrounding districts. We have found that the lakes here considered were invaded by a mollusc fauna very soon after their genesis. At least the most abundant of these species were certainly common in the surrounding lakes. Furthermore, the possibility of transport is of great importance. The lakes discussed do not seem

to have been in connection with other waters. The question has not been entirely cleared up how migration into such closed lakes takes place, but the idea is current that the transport is performed by sea birds to a great extent. Small species, such as the majority of those in the present deposits, may have good chances of being transferred by birds from one lake to another. Finally, the result of the dispersal is dependant on the ecological demands of the invading species and the ecological conditions in the new waters. The present material may indicate, to some extent, how the present species react for some ecological factors, viz. supply of calcium carbonate and nourishment and the water's content of clay particles. These questions shall be briefly touched upon.

The ecological conditions were certainly different during different stages in the development of the lakes. There is reason to assume that they were less favourable during the earliest and latest periods than during the middle one. Species occurring in the bottommost and topmost parts may be more indifferent in ecological respect than such occurring only in the middle section. From the table below showing the mollusc representation just above the *MLB* and just at the *S II* (figures in italics), it appears that the same species occur both in the bottom and the top sections of the shell-bearing layers, with the exception of the rare species *Lymnaea auricularia* and *Pisidium henslowanum*, which were observed only in the top section in one locality each. Furthermore, those species which are often abundant just above the *MLB* are also abundant just at the *S II*. The average frequency of three of these species has decreased (*Lymnaea ovata*, *Gyraulus arcticus*, and *Pisidium milium*) and that of another three has increased (*Armiger crista*, *Valvata cristata*, and *Pisidium nitidum*). These changes are not uniform, however; in the former group the frequency has increased in some deposits and in the latter the case is just the reverse. This applies also to most of the less abundant species the average frequency of

	Klingseröd II	Åskeröd	Kålstad	Rabbslådhe	Branstaby	Klingseröd I	Fossane	Average frequency
<i>Lymnaea ovata</i>	6 7	2	8 20	40 41	23 19	8 7	46 10	22 15
» <i>auricularia</i>	— —	+	— —	— —	— —	— —	— —	— +
<i>Stagnicola palustris</i>	— —	—	— —	5 5	— —	— —	— —	1 1
<i>Physa fontinalis</i>	— 1	—	— +	— —	— —	+ 2	— 1	+ 1
<i>Gyraulus arcticus</i>	+ +	19	3 1	26 26	23 9	33 2	9 17	16 10
» <i>albus</i>	+ —	+	— —	— —	1	— —	— —	+ +
<i>Armiger crista</i>	17 15	19	1 +	1 1	14 17	39 4	12 69	14 18
<i>Hippeuthis complanatus</i>	1 1	6	— +	— —	— 3	+ 3	1 1	+ 2
<i>Acroloxus lacustris</i>	+ 1	2	— —	— —	— +	+ +	— 1	+ 1
<i>Valvata cristata</i>	60 62	16	5 3	— —	14 19	+ 47	2 —	14 21
» <i>piscinalis</i>	13 12	+	— —	— —	7 12	+ —	— —	3 3
<i>Sphaerium corneum</i>	+ +	—	— —	— +	1 2	— 1	25 1	4 1
<i>Pisidium nitidum</i>	1 +	8	22 42	19 17	6 11	5 12	4 +	10 13
» <i>lilljeborgi</i>	+ +	3	— 5	2 1	— 1	1 1	— +	+ 2
» <i>subtruncatum</i>	+ +	2	1 9	2 3	— 1	5 2	— —	1 2
» <i>obtusale</i>	+ +	10	1 +	2 2	1 1	5 8	+ —	2 3
» <i>hibernicum</i>	+ +	2	6 7	1 1	1 +	+ 1	— —	1 2
» <i>milium</i>	1 1	10	53 12	2 2	10 3	2 8	+ +	11 5
» <i>henslowanum</i>	— —	—	— —	— —	— —	1	— —	— +

which is usually highest in the top. Three species, however, show no such fluctuations: *Physa fontinalis*, *Hippeuthis complanatus*, and *Acroloxus lacustris*. In some cases they have the same frequency in the bottom and the top sections; but their frequency is highest in the top section for the most part. In no case is the frequency highest in the bottom part.

We shall first consider those species which do not occur just above the *MLB* (*Lymnaea auricularia* and *Pisidium henslowanum*). The high percentage of minerogene fine-particles in the water during the first time after the separation of the lakes from the sea might have been unfavourable. Moreover, the supply of calcium carbonate might have been insufficient during this early stage, as these species are calciphile (BOYCOTT 1936). Against that argues the fact that the calciphile species *Stagnicola palustris* is abundant just above the *MLB* in one locality (Rab-balshede). However, the scanty representation of these species does not permit definite conclusions in these respects. Their presence during later stages in a few lakes may not have been caused by a better supply of calcium carbonate, since the sediments containing their shells are not different from those which are devoid of them. Nor have special thermal conditions caused their appearance in a few lakes. Most likely, these species were rare in the surroundings and the chances of dispersal were thus restricted. This may also be an important reason why *Stagnicola palustris* occurs only in two deposits. This species, which is eurythermal and calciphile, could certainly have found appropriate conditions in all the lakes investigated. This is indicated by the fact that it was rather abundant in those localities to which it happened to be transferred.

Secondly we shall consider some species which have the highest frequency in the top of the strata but are generally absent just above the *MLB*: *Physa fontinalis*, *Hippeuthis complanatus* and *Acroloxus lacustris*. Since phytogene fine-particles are most abundant in the upper part of the strata the good supply of food may be assumed to have been an important reason for the abundance of the species there. Furthermore, the increase of the macrovegetation, which is a suitable substratum for *Physa* and *Acroloxus*, may have been of importance. It is noticeable, however, that these species accompanied each other since *Physa* lives in agitated water, whereas *Acroloxus* definitely prefers stagnant surroundings acc. to BOYCOTT 1936, pp. 142 and 145. In the present case the water was stagnant. As regards *Physa*, other factors — in the first place very likely a good supply of food and a suitable substratum — may thus have given the demands of an agitated water a secondary importance. HUBENDICK (1947, p. 476) found that, in southern Sweden, the species is more characteristic of lakes than of running waters. Concerning *Hippeuthis* and *Acroloxus*, the demands of a rich supply of calcium carbonate have possibly been resigned. These species are considered calciphile (BOYCOTT 1936), but they have apparently borne the decrease in calcium carbonate supply which occurred during the formation of the uppermost part of the shell-bearing layer. It is, however, impossible to decide whether the percentage of calcium carbonate in the water was below that which is necessary for these species. They may possibly owe their absence in the Flöghult deposit to that reason.

In a third group the remaining species may be ranged which are more or less abundant both just above the *MLB* and in the uppermost part of the shell-bearing strata. These species may be very indifferent in ecological respects. They had, apparently, the ability to endure the great supply of clay particles during the first period of the lakes as well as the imperfect supply of nourishment which can be

supposed to have existed during this stage. They held their positions during the favourable middle period of the lifetimes of the lakes. At that stage the supply of calcium carbonate was very good and that of food obviously also sufficient. The quantities of decaying plants were not yet so large that the oxygen in the water was greatly consumed by the decomposition. During the following stage the species profited by the good supply of food. It is also probable that some of the enemies of the molluscs, e. g. the fishes, had disappeared at that time. On the contrary, some important disadvantages had appeared. The calcium carbonate supply had diminished, and the humus substances had increased. The oxygen was used up to a great extent by the decomposition of great quantities of plant remains. The content of sulphur had likely increased in the stagnant water. The peril of drying up was great. The vegetation was very dense which has been stated to be unfavourable for gastropods (BOYCOTT 1936). Species living in such surroundings must have special ability to endure bad conditions.

Summary. The frequency of some species and also of higher taxonomic units has undergone conformable and synchronous changes. But the material also gives examples of different groupings of species and various changes in proportions and order of succession. We found that only a restricted number of species lived in each ancient lake, as is the case in such lakes in our day too. Moreover, the mollusc fauna chiefly consisted of the same species in the different lakes — mainly the same species as those living in small lakes in the greater part of Sweden today. Most of these species were, as a rule, abundant all through the shell-bearing strata. Data presented above indicate that they are very indifferent in ecological respects; as regards some of them, this has also been shown in recent surroundings. One might imagine that these species had to withdraw during the middle period of the lifetime of the lakes on behalf of other species favoured by the better ecological conditions which were apparently prevailing during that period. The fluctuations of their frequency curves are, however, not caused by such circumstances. They give the impression of being more or less accidental, induced during a continual competition within a limited area. As soon as the frequency of one or more species had diminished for some reason, other species seized the opportunity to increase in number. It is comprehensible how accidental such changes can be, when we consider that sea birds, during a few years, are able to destroy the mollusc fauna in small lakes to a great extent. Fishes also can reduce the numbers of one or more species. Infant susceptibility is high among molluscs and mortality in the young can strike one species more than another or a group of species more than others. Thus I cannot find that there are possibilities of establishing the causes of these various changes in frequency of molluscs in the ancient small lakes, any more than the reason is always known why representation and frequency are changing from time to time in modern waters.

Distribution of ostracod shells

Shells of ostracods were observed in all deposits, except one (Korndalen). They are referable only to a few species listed in the table on p. 149. The ostracod fauna is represented by shells belonging exclusively to the genus *Candona* in six localities; three other deposits also contain *Pionocypris vidua* (MÜLLER). Only in one locality are the ostracods more abundant in species and individuals (Fossane).

The *Candona* shells occurring are hardly determinable specifically. For this

reason they are mentioned by the name of *Candona* sp. The majority of them are probably referable to *Candona candida* (MÜLLER); but shells of *Candona neglecta* SARS are possibly also present.

The *Candona* shells are in the majority in all deposits. As a rule, their frequency increases upwards in the strata. In deposits poor in ostracods single *Candona* shells may occur in any part of the bed. They have been observed even in brackish and sea water sediments. The latter phenomenon was observed at Kålstad (p. 120). Also in the other species an increasing frequency towards the top of the shell-bearing strata was observed, with the exception of *Herpetocypris reptans* BAIRD.

The fact that the number and the individual frequency of ostracodal species had increased considerably in the Fossane locality which is younger than the remaining ones is possibly a consequence of climatic amelioration.

Marine species were found in the lacustrine part of several deposits: *Hemicythere emarginata* SARS, *Cytheridea papillosa* BOSQUET, and especially *Cythere lutea* MÜLLER. They are obviously redeposited from marine deposits. They are sometimes fairly numerous in the bottommost part, but may also appear in the higher sections of the shell-bearing layers, though decreasing in number upwards (cf. Klingseröd II). A brackish water form — *Cyprideis littoralis* BRADY — was found in one locality (Hjelpedsten).

Average number of species observed in each deposit (Kålstad only qualitatively investigated):

	Flöghult	Klingseröd II	Askeröd	Kålstad	Rabbalshede	Branstaby	Klingseröd I	Stuvången	Hjelpedsten	Fossane
<i>Candona</i> sp.....	+	+	+	+	16	+	3	8	9	533
<i>Iliocypris gibba</i> (RAMDOHR)	—	—	—	—	—	—	—	—	—	4
<i>Iliocyprilla bradyi</i> G. O. SARS	—	—	—	—	—	—	—	—	—	5
<i>Heterocypris incongruens</i> (RAMDOHR) ...	—	—	—	—	—	—	—	—	—	36
<i>Herpetocypris reptans</i> (BAIRD)	—	—	—	—	—	—	—	—	—	2
<i>Pionocypris vidua</i> (MÜLLER)	—	—	—	—	—	—	+	1	1	46
<i>Darwinula</i> cf. <i>stevensoni</i> (BRADY and ROBERTSON)	—	—	—	—	—	—	—	—	—	+
<i>Cyprideis littoralis</i> BRADY	—	—	—	—	—	—	—	—	1	—
<i>Cythere lutea</i> MÜLLER	—	—	—	+	1	+	3	—	—	—
<i>Hemicythere emarginata</i> G. O. SARS....	—	—	—	—	+	—	—	—	—	—
<i>Cytheridea papillosa</i> BOSQUET	—	—	—	—	—	—	—	—	1	—

The ecology of freshwater ostracods is imperfectly known. On account of the scanty representation the above material can hardly contribute to a better knowledge in this respect. It indicates, however, that *Candona* has obviously a great capacity for enduring different ecological conditions, judging from the fact that it was found in brackish water layers and in all parts of the calcareous freshwater deposits.

The fact that the ostracods, as a rule, are most abundant in the upper part of the shell-bearing layers may have been caused by the good supply of nourishment consisting of decaying plant remains and dead molluscan bodies; vegetation and molluscs were very abundant during that period. Some other ecological conditions

were, however, not favourable: the supply of oxygen was certainly poor and the percentage of sulphur, on the contrary, rather high on account of decomposition of great quantities of plasma. In addition, the supply of calcium carbonate had diminished. Thus, the freshwater ostracods here considered seem to be rather indifferent as regards several ecological factors; but, a good supply of food is apparently very important to enable them to thrive. In studying living ostracod communities I have found that they have a remarkable ability to endure very bad conditions in the stagnant water of small and shallow ponds and ditches.

Other freshwater organisms

Statoblasts of *Cristatella* cf. *mucedo* are abundant. Eggs of Turbellaria rhabdocoela and a kind of cocoon generally ascribed to *Dendrocoelum lacteum* were often found. Cocoons belonging to *Chaetogaster* were noticed in one locality. Ephippia were observed rather often; their appearance corresponds closely to that of *Daphnia pulex*. Fragments of insects were also often found. A rather well preserved coleopter was observed in the Kålstad deposit. Remains of fish skeletons appear in practically all the shell-bearing layers.

	Flöghult	Klingseröd II	Askeröd	Kålstad	Rabalskede	Branstaby	Klingseröd I	Stuvängen	Hjelpedsten	Korndalen	Fossane
Turbellaria:											
Eggs of Rhabdocoela	—	—	+	—	—	+	+	—	+	—	—
<i>Dendrocoelum</i> cf. <i>lacteum</i> MÜLLER	+	+	—	—	—	+	—	+	+	—	—
Oligochaeta:											
<i>Chaetogaster</i> sp.	—	—	+	—	—	—	—	—	—	—	—
Phyllopoda:											
<i>Daphnia pulex</i> DE GEER.	—	—	—	+	+	+	+	+	—	—	—
Bryozoa:											
<i>Cristatella</i> cf. <i>mucedo</i> CUVIER	—	+	—	+	+	+	+	+	+	—	+
Insecta	—	+	—	+	—	+	+	+	+	+	—
Pisces	—	+	+	+	+	+	+	+	+	+	+

Vegetation

In the latter part of the 19th century and the beginning of the present the Quaternary distribution of vascular plants, inter alia hydrophytes, was studied by several scientists. In this way they intended to elucidate the development of Quaternary climate and also to elaborate a dating scheme. As a consequence of the fact that pollen analysis has appeared to be superior for the purpose of dating, the interest in the macrofossils of plants diminished, however. Yet, there is reason to continue the investigation of them. Intense studies during recent years of the correspondence between hydrophytes and the chemical and physical conditions of the water have increased the possibilities of basing conclusions as regards the hydrology of ancient lakes on the remains of their flora. The aim of my investigation into the plant life of the ancient lakes here considered was above all to obtain a knowledge of the surroundings where the shell-bearing organisms lived. In addition, the floristic

data in this paper may be of some value in future investigations which have the main purpose of studying the development of our hydrophyte flora during the Quaternary. The following table is a survey of the species observed:

	Flöghult	Klingseröd II	Askeröd	Kålstad	Rabbalshede	Branstaby	Klingseröd I	Stuvängen	Hjelpedsten	Korndalen	Fossane
Charophyta	+	+	+	+	+	+	+	+	+	+	+
<i>Pinus silvestris</i> L.											
<i>Potamogeton obtusifolius</i> M. and K.		+			+	+	+		+		
" <i>pectinatus</i> L.	+	+				+	+	+	+	+	
" <i>filiformis</i> PERS.						+	+				
" <i>natans</i> L.	+		+			+	+	+	+	+	
" <i>perfoliatus</i> L.						+	+	+	+	+	
" <i>gramineus</i> L.			+			+		+	+	+	
" <i>trichoides</i> CHAM. and SCHL.								+	+	+	
" <i>praelongus</i> WULF.	+		+					+			
" sp.								+			+
<i>Ruppia rostellata</i> KOCH					+			+	+		
" <i>spiralis</i> L.; DUM.								+			
" sp.								+			
<i>Zannichellia repens</i> BOENN. L.										+	
<i>Najas marina</i> L.								+	+		
<i>Alisma plantago-aquatica</i> L.										+	
? <i>Catabrosa aquatica</i> (L.) PB.						+					
<i>Scirpus lacustris</i> L.		+	+	+		+	+	+			
" <i>maritimus</i> L.			+			+	+	+			
" sp.						+	+				
? <i>Rhynchospora alba</i> (L.) VAHL.						+	+	+	+		
<i>Carex</i> cf. <i>stellulata</i> GOOD.						+					
" cf. <i>hornschuchiana</i> HOPPE		+									
" cf. <i>pulchella</i> LÖNNR.								+			
" <i>canescens</i> L.										+	
" spp.		+	+	+	+	+	+	+	+	+	
<i>Juncus</i> sp.								+			
<i>Betula</i> cf. <i>verrucosa</i> ERH.				+					+		
" sp.											
<i>Polygonum</i> cf. <i>persicaria</i> L.										+	
" cf. <i>hydropiper</i> L.										+	
" sp.					+					+	
<i>Atriplex</i> spp.										+	
? <i>Montia lamprosperma</i> CHAM.										+	
<i>Nymphaea alba</i> L.		+	+	+		+	+	+	+		+
<i>Ceratophyllum submersum</i> L.							+	+	+		
<i>Ranunculus</i> cf. <i>peltatus</i> SCHRANK.					+					+	
" spp.		+	+		+			+			
<i>Comarum palustre</i> L.		+				+					
<i>Hypericum</i> sp.							+				
<i>Myriophyllum spicatum</i> L.					+	+	+			+	
" cf. <i>alterniflorum</i> L.						+				+	
<i>Hippuris vulgaris</i> L.					+					+	
<i>Empetrum nigrum</i> L.					+						
<i>Arctostaphylos uva ursi</i> SPR.			+			+					
<i>Naumburgia thyrsiflora</i> RCHB.						+				+	
<i>Menyanthes trifoliata</i> L.		+	+		+	+				+	
<i>Lycopus europaeus</i> L.								+			

I. HESSLAND, *Calcareous freshwater sediments from northern Bohuslän*

The table below shows the average frequency of the genera in the deposits. (Kålstad is excluded, since the examination was only qualitative.)

	Flöghult	Klingsröd II	Askeröd	Rabbslshede	Branstaby	Klingsröd I	Stuvången	Hjelpedsten	Korndalen	Fossane	Average frequency
<i>Pinus</i>	15	3	55	40	2	44	16	<1	53	8	<1
<i>Potamogeton</i>							9	<1	<1		24
<i>Ruppia</i>									1		1
<i>Zannichellia</i>											
<i>Najas</i>							<1	18			2
<i>Alisma</i>									<1		<1
? <i>Catabrosa</i>					<1						<1
<i>Scirpus</i>		4	3		10	5		1	<1		2
? <i>Rhynchospora</i>					<1				<1		<1
<i>Carex</i>		1	<1	4	2	3	<1	5	8		2
<i>Juncus</i>							<1				<1
<i>Betula</i>							<1	<1			<1
<i>Polygonum</i>				<1							<1
<i>Atriplex</i>									<1		<1
? <i>Montia</i>									<1		<1
<i>Nymphaea</i>		<1	<1		<1	<1	<1	2		4	<1
<i>Ceratophyllum</i>							<1				<1
<i>Ranunculus</i>		<1	<1	<1				<1	<1		<1
<i>Comarum</i>		<1			<1						<1
<i>Hypericum</i>							<1				<1
<i>Myriophyllum</i>				2	<1	<1			1		<1
<i>Hippuris</i>				<1					1		<1
<i>Empetrum</i>				<1							<1
<i>Arctostaphylos</i>						<1					<1
<i>Naumburgia</i>					<1				<1		<1
<i>Menyanthes</i>		<1	<1	<1		<1			<1		<1
<i>Lycopus</i>								<1			<1

Most of the species are autogene. Seeds of such species as *Pinus*, *Betula*, *Empetrum*, and *Arctostaphylos* are, on the other hand, allogene — carried there by winds, running water, or by birds. One or other of the gramineous seeds is certainly also allogene.

About 50 per cent of the species were found only in one locality, and about 40 per cent in 2–4 localities. Ten per cent were found in 6–8 localities. No phanerogamous species were observed in all deposits. A comparison with the distribution of the genera shows that about 75 per cent of them are represented in 1–4 localities. The rest occur in 5–11 localities. The average frequency of the genera is generally low: about 80 per cent of them have a frequency < 1 fruit per 100 g sediment and 15 per cent occur in an average number of 1–2. Only *Potamogeton* has a high frequency (on an average 24 seeds per 100 g sediment). This genus and the Charophytes are represented in all the deposits.

It may be of interest to see to what extent species migrated into the new ponds immediately after their formation. These species are mentioned in the first column of each locality in the table on p. 153. The last column presents the species found just at the *S II*. The middle one shows the mean frequency in the samples between the bottommost and the topmost ones. (*Betula* and *Arctostaphylos* are certainly allogene.)

	Klingse- röd II	Aske- röd	Kål- stad	Råbals- hede	Bransta- by	Klingse- röd I	Fossane
<i>Potamogeton pectinatus</i> .	3 — —			68 43 27	— — 2		
» <i>gramineus</i> .		1			— 1 1		
» <i>natans</i> . . .		72			— 1 1		
» <i>obtusifolius</i>	5 — 2			— 1 —		— <1 —	
» <i>filiformis</i> . .						12 34 19	
» <i>perfoliatus</i> .						2 1 4	
» <i>sp.</i>						— <1 —	
? <i>Catabrosa aquatica</i>					1 — —		14 2 8
<i>Scirpus lacustris</i>	2 7 —	5	+		— 10 1	2 — 23	
» <i>maritimus</i>					4 18 1	— <1 —	
» <i>sp.</i>					— 4 —	— <1 —	
? <i>Rhynchospora alba</i>					— — 1		
<i>Polygonum sp.</i>				— <1 —			
<i>Carex cf. stellulata</i>					— 2 1		
» <i>cf. hornschiiana</i>							— <1 —
» <i>sp.</i>	— 2 —			3 5 1	1 4 1	4 2 12	
<i>Nymphaea alba</i>	— 2 —	2	+		— 1 1	— 1 —	10 2 —
<i>Ranunculus cf. peltatus</i>				1 — —			
» <i>sp.</i>	— <1 —						
<i>Comarum palustre</i>	— <1 —				1 — —		
<i>Myriophyllum spicatum</i>				1 2 4	1 — —	— <1 —	
» <i>cf. alterniflorum</i>					1 — —		
<i>Menyanthes trifoliata</i> . .	2 — —	1		— 1 —		— — 2	
<i>Betula sp.</i>						— <1 —	
<i>Arctostaphylos uva ursi</i>			+			— <1 —	

The Charophytes are not mentioned in the table above. This group is represented by oospores in all deposits; they occur at the *MLB*, the *S II*, and in the intervening horizons. They were also observed in marine sediments just below the *MLB* (Kålstad). This obviously coincides with the fact that several species are halophilous (OLSEN 1944, pp. 189 and 204). Since the Charophytes were not determined, I cannot say whether the species from the marine or the brackish water sediments are identical with those occurring in the pure freshwater layers. Differences in the appearances of the oospores were not discernible; but this does not mean that they belong to the same species, since it may hardly be possible to determine oospores specifically. As a rule, the frequency is much lower at the *MLB* and at the *S II* than in the intervening part of the deposits where the content of calcium carbonate is higher. In a few deposits it was observed that oospores appearing in samples with a high content of calcium carbonate were freely encrusted, and, on the contrary, that those occurring in samples with an inferior content — bottom and top sections — were not covered with calcium carbonate. In the greater number of deposits the oospores were not encrusted, however, in spite of the fact that the sediment is partly very calcareous. The abundance of Charophytes in these ancient lakes is certainly due to the fact that the water had a considerable content of calcium carbonate (cf. OLSEN 1944, p. 201). Moreover, the abundance of Charophytes indicates that the action of the water was very slight (cf. OLSEN 1944, p. 190).

One phanerogamous species was observed in the uppermost part of the marine section of one stratal sequence, viz. *Scirpus maritimus* (Branstaby). This species is today "am ausgeprägtesten an die Meeresbuchten gebunden. In süßem Wasser — nur ganz vereinzelte Standorte" (SAMUELSSON 1934, p. 24). It has been observed

to live in lakes and ponds separated from the sea; in some cases it has been proved that sodium chloride was supplied at high water or by the ground water. SAMUELSSON also mentions that the species has been found in lakes above the highest marine limit; in these cases the water is calciferous. SAMUELSSON states that the calcium carbonate compensates the sodium chloride; the species should not be exclusively calciphile. The present investigation shows that *Scirpus maritimus* was fairly abundant in lakes separated from the sea; the high percentage of calcium carbonate in the water may have been one important reason for that.

Some of the species mentioned live today not only in freshwater but also in brackish water: *Potamogeton pectinatus*, *P. filiformis*, and *Myriophyllum spicatum*. They occur not only just above the MLB, but also in the middle and upper parts of the calcareous strata. They are very calciphile; to other nutritious substances both the *Potamogeton* species are stated to be rather indifferent, whereas *Myriophyllum* is stated as oligo-eutrophic (SAMUELSSON 1934, pp. 30, 58, and 57).

The rest of the species occurring just above the MLB are pure freshwater species (*Potamogeton obtusifolius*, ?*Catabrosa aquatica*, *Carex* sp., *Comarum palustre*, *Myriophyllum* cf. *alterniflorum*, *Nymphaea alba*, *Scirpus lacustris*, *Menyanthes trifoliata*, and *Ranunculus* cf. *peltatus*). Some of them are abundant in the middle and upper parts of the strata, viz. *Potamogeton obtusifolius*, *Nymphaea alba*, *Scirpus lacustris*, and *Menyanthes trifoliata*. The occurrence of *Menyanthes* just above the MLB in one locality is an exception; as a rule, this species seems to have migrated into the lakes first during their later existence. None of the species seems especially to require nutritious salts. The content of calcium carbonate in the water was apparently not an important reason for their immigration. Two species (*Myriophyllum alterniflorum* and *Ranunculus* cf. *peltatus*) may instead be said to have migrated in spite of the fact that the water was calciferous; they are considered to avoid calciferous waters, though they have also been found in such surroundings (SAMUELSSON 1934).

A few species were not found in the bottom part of the shell-bearing layers but higher up, viz. species referable to *Potamogeton* and *Carex* in the first place. The *Potamogeton* species (*P. gramineus*, *P. natans*, and *P. perfoliatus*) are rather eutrophic; the last-mentioned also occurs in brackish water (SAMUELSSON 1934).

A few species of special interest were observed in separate samples in some deposits. Among them is *Ruppia* which was found in three deposits. *R. rostellata* was the most abundant, *R. spiralis*, on the contrary, was very rare. Nowadays these species live in salt or brackish water. In our deposits the fruits were found in the lower part of freshwater strata. Whether they are redeposited or the specimens really lived in the ancient lakes may be difficult to decide. Since all the samples with the exception of one (Hjelpedsten) contain redeposited marine shells the fruits of *Ruppia* might be suggested to be redeposited, too. The fact that the long and fragile fruit stalks are generally unbroken argues against redeposition, however.

Among the species which attract special interest are also *Zannichellia repens* and *Najas marina*. In our day these species occur in brackish water for the most part, but during earlier periods they seem to have lived in fresh water to a greater extent than today. *Zannichellia* was observed only in one locality (Korndalen). The lacustrine sediment is here mixed up with rather a large number of marine shells. The fruits of *Zannichellia* may also be of marine origin. *Najas* was found in two localities (Hjelpedsten and Stuvängen). At Hjelpedsten it occurs in all samples with a high frequency. *Najas* is here the most abundant species (on an average

18 fruits per 100 g sediment). At Stuvängen the frequency is not so high. In both the localities the fruits were found in samples with redeposited marine shells and also in those without such. The latter are in majority. *Najas* obviously lived in fresh water here. It was possibly favoured by the high content of calcium carbonate in the water.

Some more species will be briefly mentioned.

Potamogeton praelongus was found in some deposits. It is not very eutrophic but possibly favoured by calcium carbonate. Today it seems to be rather common in this area.

Potamogeton trichoides lives in the present day, within Scandinavia, chiefly in the Scano-Danian area. It occurs in calcareous water and is obviously rather in need of nutritious substances. This species was found in two Bohuslän deposits (Hjelpedsten and Stuvängen). The reason for the appearance of *Potamogeton trichoides* may be a favourable climate, but, perhaps in the first place, appropriate nutritious conditions. It still occurs in some localities in the surroundings of Göteborg (SAMUELSSON 1934, p. 98).

Ceratophyllum submersum was found in the same deposits as was *Potamogeton trichoides*. It shows similarities to this species in distributional and ecological respects. During earlier Quaternary periods the distribution of this species was more northern than today, when, in Scandinavia, it is practically restricted to Denmark. This retreat may, in the first place, have been caused by deterioration of ecological conditions (HESSLAND 1946). The ecological demands of *Ceratophyllum submersum* are not perfectly cleared up, but the species is considered eutrophic and in need of calcium carbonate.

Lycopus europaeus — observed in one locality (Hjelpedsten) — had also a wider distribution during earlier periods. This is generally considered to be caused by the amelioration of climate.

The remaining species are of minor interest. They occur sporadically. A few of them are uncertain as to the determination. Some are allogene. Those autogene are rather indifferent in ecological respects.

I had expected to find two further species, which are of importance in Quaternary geology: *Cladium Mariscus* R. BR. and *Najas flexilis* (WILLD). The ecological conditions of the lakes investigated may have been favourable for them. Subfossil *Cladium* has been found in this area before (v. POST 1925). *Najas flexilis*, on the other hand, has not been observed here (SANDEGREN 1941). I actually found some seeds of *Najas* with rows of oblong tissue cells, but these specimens were worn so that the cells in reality belong to the sub-cortical layer. The multiangular cortical cells typical of *Najas marina* did, however, appear in certain better preserved sections. Thus, these specimens are referable to *Najas marina*. The most northern localities of subfossil *Najas flexilis* in western Sweden hitherto known are situated in the surroundings of Göteborg (SANDEGREN 1941, map p. 63).

Summary. The most common plants in the small ancient lakes investigated are Charophytes and *Potamogeton* species. The abundance of Charophytes indicates that the water was tranquil. The presence of these organisms and of fanerogamous species doing well in eutrophic waters with a good supply of calcium carbonate indicates, furthermore, that the ancient lakes offered favourable conditions for eutrophic plants. Recent lakes with such a vegetation are distinguished by an abundant molluscan fauna.

Climatic evidences of the fauna

Important data as regards Quaternary climate might be expected to be gained from subfossil shell-bearing freshwater organisms. Earlier, this idea was current; molluscs especially were investigated on that account. Most of these investigations are rather old, and the datings are hardly perfectly reliable which, of course, diminishes the climatologic importance of the finds. Later finds, dated by means of pollen analyses, are more important in this respect. Unfortunately, however, only little attention has been paid to the zoogene constituents in the shell-bearing freshwater sediments during the most recent decades, though such deposits have been observed in great numbers in different parts of Sweden, especially during field works for geological maps. Many of them have been accurately dated by means of pollen analyses.

The thermal demands of several mollusc species are rather well known, but other species are incompletely investigated in this respect. The knowledge of freshwater molluscan distribution within Sweden is based to a great extent on the researches of WESTERLUND during the latter part of the last century. Later finds kept in the Swedish State Museum are partly unpublished, but some of them are given by HUBENDICK 1947; however, Prof. N. ODHNER and Dr. B. HUBENDICK have informed me about the distribution of those which were not published by HUBENDICK. The distribution of freshwater molluscs in Norway is very imperfectly known, but in Finland their occurrence has been better investigated.

Our knowledge of the present distribution of freshwater ostracods in Fennoscandia is still more imperfect than that of the molluscs. Literary data on their recent distribution are very few on account of scanty field investigations.¹ The Quaternary representation is particularly imperfectly known. As ostracods are widely spread in lakes, ponds, and ditches, stenothermal species will certainly be useful as climatic indicators after their thermal demands have become better known. Unfortunately, shells of the widely dispersed genus *Candona* cannot be utilized for this purpose, since these shells are hardly determinable with certainty.

The freshwater species belonging to other animal groups observed during this investigation are few and of minor interest in this connection.

As a matter of fact, highly eurythermal species are not suitable as climatological indicators. A future revision of such species may, perhaps, lead to the distinguishing of climatologically restricted subspecies or varieties. Until then, we must employ collective names, and desist from using these species for conclusions as regards Quaternary climate. The following species may thus be excluded as unsuitable climatic indicators on account of their being considered highly eurythermal. (Distribution of molluscs mainly in accordance with EHLMANN 1933, GEYER 1927, HUBENDICK 1947, and with information given by Prof. N. ODHNER and Dr. B. HUBENDICK; distribution of ostracods in acc. with ALM 1915, SARS 1922-1928, and oral communication by Dr. O. ELOFSON.)

¹ "Monographie der schwedischen Süsswasser-Ostracoden" by ALM (1915) is the most complete paper on Swedish freshwater ostracods. Earlier, our principal literature on that subject consisted of some papers on ostracods by LILLJEBORG. During this century, EKMAN (in addition to ALM) has enlarged our knowledge of the present distribution of freshwater ostracods in Sweden as well as of their biology.

Succinea cf. *putris*: Not determined with certainty, since shell characters are hardly sufficient to distinguish Swedish *Succinea* species. The range of *S. putris* includes the whole of Fennoscandia, except the most northern parts of Sweden, Norway, and Finland (ODHNER).

Lymnaea ovata and *Stagnicola palustris*: All Fennoscandia.

Valvata piscinalis: Found in northern Swedish Lappland; the same latitude in Finland (HUBENDICK).

Sphaerium corneum: Distribution mainly = that of *Valvata piscinalis* (HUBENDICK). ODHNER thinks that *S. corneum* has partly been confused with *S. nitidum*.

Pisidium nitidum, *P. lilljeborgi*, *P. milium*, and *P. obtusale*: All, or practically all Fennoscandia.

Pisidium hibernicum and *P. subtruncatum*: Apparently known from the whole of Norrland (ODHNER).

Pisidium henslowanum: Apparently not the whole of Norrland (ODHNER).

Pionocypris vidua, *Heterocypris incongruens*, and *Candona* sp.: Apparently all Fennoscandia. The *Candona* shells may chiefly belong to *C. candida* and a few to *C. neglecta*. Both these species are found in practically all Fennoscandia.

Most of these species were found in the Flöghult deposit which was accumulated during the retreat of the Ice from the Bergslagen in the middle Sweden to Jämtland; the remaining species appear in strata accumulated during the latest part of this recession.

The following data may give an idea of the earliest appearance of the species now mentioned in other parts of southern Sweden:

Succinea putris: Boreal in Scania (ODHNER 1910).

Lymnaea ovata: In Scania late-glacial (ODHNER 1910: sub-Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal and possibly older). In Gotland Arctic and sub-Arctic (ODHNER 1910). In Västergötland Arctic (ODHNER 1910). In addition known from a great number of localities of various ages in different parts of Sweden.

Stagnicola palustris: In Scania late-glacial (ODHNER 1910: sub-Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal). In Gotland late-glacial (ODHNER 1910: Arctic and sub-Arctic; MUNTHER-HEDE-LUNDQVIST 1927, p. 86: Boreal [pollen analysis]; MUNTHER-HEDE-v. POST 1925, p. 64: in *Ancylus* deposits).

Valvata piscinalis: In Scania late-glacial (ODHNER 1910: sub-Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: sub-Arctic and Boreal). In Halland sub-Arctic (ODHNER 1910). In Gotland in *Ancylus* deposits (MUNTHER-HEDE-v. POST 1925, p. 64). In Östergötland late-glacial (MAGNUSSON-MUNTHER-ROSEN 1922, p. 100; SANDEGREN-SUNDIUS 1926, p. 85: Boreal [pollen analysis]).

Sphaerium corneum: In Scania late-glacial (HOLST 1911, p. 91; MUNTHER-JOHANSSON-GRÖNWALL 1920, p. 135; ODHNER 1910: sub-Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: sub-Arctic and Boreal). In Gotland and Uppland Boreal (ODHNER 1910). In Östergötland late-glacial (MAGNUSSON-MUNTHER-ROSEN 1922, p. 103 f.: above the *Ancylus* limit; SANDEGREN-SUNDIUS 1926, p. 85: Boreal [pollen analysis]).

Pisidium nitidum: In Scania late-glacial (KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: sub-Arctic and Boreal, cf. KURCK op. cit., p. 53 f.; MUNTHER-JOHANSSON-GRÖNWALL 1920, p. 135). In Gotland late-glacial

- (ODHNER 1910: Arctic and sub-Arctic; MUNTHE-HEDE v. POST 1925, p. 63: Ancyclus deposits; MUNTHE-HEDE-LUNDQVIST 1927, p. 86: Boreal [pollen analysis]). In Östergötland Boreal [pollen analysis] (SANDEGREN-SUNDIUS-LUNDQVIST 1924, p. 67).
- Pisidium lilljeborgi*: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 135; KURCK 1917, pollen analysis cf. ISBERG 1929: Boreal). In Gotland Postglacial (MUNTHE-HEDE-v. POST 1925, p. 63: Ancyclus deposits; MUNTHE-HEDE-LUNDQVIST 1927, p. 86: Boreal [pollen analysis]). In Östergötland below the Ancyclus limit (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 105). In Västergötland Boreal (SANDEGREN 1916, p. 54).
- Pisidium milium*: In Scania interstage and late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 135; WESTERGÅRD 1912, p. 42; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal and possibly older; cf. KURCK op. cit., p. 53 f.). In Gotland Postglacial (MUNTHE-HEDE v. POST 1925, p. 63: Ancyclus deposits; MUNTHE-HEDE-LUNDQVIST 1927, p. 86; Boreal [pollen analysis]). In Östergötland in deposits above the Ancyclus limit (MAGNUSSON MUNTHE-ROSÉN 1922, p. 103).
- Pisidium obtusale*: In Scania interstage and late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 135; HOLST 1911, p. 97; ODHNER 1910: sub-Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal). In Gotland late-glacial (ODHNER 1910: Arctic and sub-Arctic; MUNTHE-HEDE-LUNDQVIST 1927, p. 86: Boreal [pollen analysis]). In Östergötland Boreal [pollen analysis] (SANDEGREN-SUNDIUS-LUNDQVIST 1924, p. 67).
- Pisidium hibernicum*: In Gotland Postglacial (MUNTHE HEDE v. POST 1925, p. 63: Ancyclus deposits; MUNTHE HEDE-LUNDQVIST 1927, p. 86: Boreal [pollen analysis]). In Östergötland Boreal [pollen analysis] (SANDEGREN-SUNDIUS-LUNDQVIST 1924, p. 67). In Jämtland early Atlantic [pollen analysis] (BOOBERG 1930, p. 218).
- Pisidium subtruncatum*: In Scania interstage and late-glacial (MUNTHE JOHANSSON-GRÖNWALL 1920, p. 135; KURCK 1917, pollen analysis cf. ISBERG 1929: Boreal). In Gotland Postglacial (ODHNER 1910: Boreal; MUNTHE-HEDE-v. POST 1925, p. 63: Ancyclus deposits; MUNTHE-HEDE-LUNDQVIST 1927, p. 86: Boreal [pollen analysis]). In Östergötland in a deposit below the Ancyclus limit (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 105).
- Pisidium henslowanum*: In Scania late-glacial (HOLST 1911, p. 91; ODHNER 1910: Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal). In Gotland in an Ancyclus deposit (MUNTHE-HEDE-v. POST 1925, p. 63).
- Pionocypris vidua* and *Heterocypris incongruens* do not seem to have been observed earlier in Swedish Quaternary deposits.
- Candona candida*: Numerous statements on subfossil finds (cf. above as to the difficulty of distinguishing this species from nearly related ones). In Scania interstage and late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 135; HOLST 1908, p. 8). In Gotland and Uppland late-glacial (MUNTHE 1910, p. 14; NATHORST 1893, p. 576).
- Candona neglecta*: In Scania late-glacial (HOLST 1908, p. 9). In Gotland in a sub-Litorina deposit (MUNTHE 1910, p. 80).

Judging from these data the eurythermal species mentioned here seem to have appeared within other parts of southern Sweden mainly as early as in Bohuslän.

In a second group we can gather some species which are rather eurythermal, though not in so high a degree as the group discussed above. The climatological importance of these species is thus somewhat limited.

Lymnaea auricularia: Found just south of the Arctic Circle in Sweden and just north of it in Finland. The localities are, in Sweden, situated along the Norrland coast (HUBENDICK). This species is perhaps somewhat overlooked on account of the fact that the shells are not always very characteristic.

Armiger crista: Found in Norrland only at Östersund and in Västerbotten (to Piteå); Finland only along the S. coast and S of Kuopio, N. Finland only at Uleåborg; S. Norway, vicinity of the Trondheimfjord, and S of Tromsö (ODHNER).

Physa fontinalis: Seems to be least eurythermal of the species gathered in this group. Continual range reaches apparently about 64° N; a single find reported from the Pite River 65 1/2° N (HUBENDICK).

Valvata cristata: Mainly in the Bergslagen, isolated occurrences in Jämtland and northernmost parts of the Bothnian coast, in Finland sporadically to about 63° N.

In the Bohuslän deposits these species appear practically as early as the highly eurythermal ones, viz. during the later part of the retreat of the Ice just towards Jämtland, thus at the end of the Finiglacial period.

The earliest appearance of these four species within other parts of southern Sweden is indicated by the following data:

Lymnaea auricularia: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 165; HOLST 1911, p. 103; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal and sub-Arctic, also cf. KURCK op. cit., p. 53 f.). In Gotland early Atlantic (MUNTHE-HEDE-LUNDQVIST 1927, p. 86). In Östergötland in a deposit below the Ancyclus limit (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 105).

Armiger crista: In Scania late-glacial (KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429; Boreal and sub-Arctic, also cf. KURCK op. cit., p. 53 f.). In Gotland Arctic, sub-Arctic, and Boreal (ODHNER 1910). In Östergötland in deposits above the Ancyclus limit (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 102 f.).

Physa fontinalis: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 165; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal). In Gotland Postglacial (ODHNER 1910: Boreal; MUNTHE-HEDE-V. POST 1925, p. 64: in an Ancyclus deposit). In Östergötland in a deposit above the Ancyclus limit (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 102).

Valvata cristata: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 165; ODHNER 1910: sub-Arctic; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429; Boreal, also cf. KURCK op. cit., p. 53 f. and NILSSON op. cit., p. 450: sub-Arctic or ?Arctic). In Halland sub-Arctic (ODHNER 1910). In Gotland Postglacial (MUNTHE-HEDE-LUNDQVIST 1927, p. 86: Boreal; MUNTHE-HEDE-V. POST 1925, p. 64: in Ancyclus deposits). In Östergötland late-glacial (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 100; SANDEGREN-SUNDIUS 1926, p. 85: Boreal [pollen analysis]).

As was the case with the group of the highly eurythermal species, there seems to be a rather good agreement as to the appearance of the second group species in Bohuslän and other parts of southern Sweden.

The remaining species in the Bohuslän deposits can be gathered in a third group, distinguished by the fact that they have a southern range. The distribution of the ostracods is somewhat unsatisfactorily known; they are thus climatologically less important than the molluscs, whose distribution is better known.

Gyraulus albus: Most northern finds in Sweden made in Helsingland (ODHNER and HUBENDICK); in Norway and Finland found somewhat more to the north (HUBENDICK). ODHNER thinks that it is questionable whether *Gyraulus albus* really occurs in Norway.

Hippeuthis complanatus: Most northern find in Sweden made in SE. Dalarne (HUBENDICK); dead shells in Jämtland (ODHNER); in Norway most northern find made at Oslo, in Finland in the lake district.

Acroloxus lacustris: Northern limit at the great bow of the river Dalälven and the southern part of the Finnish lake district. According to an unverified statement, the species should also have been observed in eastern Jämtland (ODHNER).

Iliocypris gibba and *Darwinula* cf. *stevensoni*: Do not seem to have been found north of Helsingland and Uppland, resp. In Norway observed at Oslo and Moss, resp.

Iliocyprilla bradyi: In Sweden found in Jämtland and Uppland but apparently not in the intervening region. In Norway found at Oslo.

Herpetocypris reptans: In Sweden found in northern Uppland, in Norway at Trondheim.

Cyprideis littoralis: In Sweden observed in Ångermanland (ELOFSON), in Norway at Oslo.

The molluscs of this group occur in layers accumulated as early as the previous group, i. e. during the final part of the Finiglacial period. The ostracods (with the exception of *Cyprideis littoralis*), appeared in an early part of the Postglacial period (just after the A^0); *Cyprideis littoralis* appeared between the C^0 and the A^0 .

For comparison I give some data as to the earliest appearance of these species in other provinces in southern Sweden:

Gyraulus albus: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 165; ODHNER 1910: Boreal; KURCK 1917, pollen analysis cf. ISBERG 1929: Boreal).

Hippeuthis complanatus: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 165; ODHNER 1910: sub-Arctic and Boreal; KURCK 1917, pollen analyses cf. ISBERG 1929 and NILSSON 1935, p. 429: Boreal). In Östergötland in a deposit above the Ancyclus limit (MAGNUSSON-MUNTHE-ROSÉN 1922, p. 102).

Acroloxus lacustris: In Scania late-glacial (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 165; KURCK 1917, pollen analysis cf. ISBERG 1929: Boreal). In Gotland Boreal (ODHNER 1910).

Iliocypris gibba: Interstage in Scania (MUNTHE-JOHANSSON-GRÖNWALL 1920, p. 135).

Darwinula stevensoni: In a sub-Litorina deposit in Gotland (MUNTHE 1910, p. 80).

Iliocyprilla bradyi: In Scania late-glacial (MUNTHE 1897, p. 128; HOLST 1908, p. 9).

Herpetocypris reptans: In Gotland in Ancyclus beds (MUNTHE 1910, p. 60).

Cyprideis littoralis: Said to have been found subfossil in Sweden (SARS 1925, p. 156).

This statement is possibly referable to finds of *Cytheridea torosa* JONES, of which species *C. littoralis* earlier was considered a variety (SARS, l. c.). *C. torosa* is reported from late-glacial Scanian deposits containing *Salix polaris* (NATHORST 1910, p. 550), and *C. cf. torosa* from a Litorina stratum in Gotland (v. POST 1903, p. 23).

The species of the third group seem to have appeared about contemporaneously in Bohuslän and other parts of southern Sweden.

Judging from the occurrence of the three mollusc species in the Bohuslän deposits, climate must not have been more severe at the very end of the Finiglacial period than today's climate in the Swedish Bergslagen and the Finnish lake district. This is not contradicted by the fact that *Gyraulus arcticus* and *Pisidium milium* f. *unioides* were present at the same time. These forms are considered very northern. However, as a matter of fact, they are abundant also in the Fossane deposit which was accumulated even later. These shells have not been redeposited from older sediments.

This late occurrence might be explained in such a way that they had survived as relics. If this were the case, two premises must have been fulfilled. First, the relic locality must have been separated from the main area of distribution by a vast zone devoid of the species in question. Second, the climate within the main distribution area must have differed considerably from that of the locality of the relic. It is difficult to decide whether these premises have been fulfilled, as the extension of the main distribution area at that time is not known. The assumption may not be excluded that southern Sweden was included in the main area of distribution at this time. Available statements are too scanty to prove this; *Gyraulus arcticus*, however, is recorded from an Östergötland deposit situated below the Ancyclus limit (MAGNUS-SON-MUNTHE-ROSÉN 1922, p. 105). *Gyraulus arcticus* as well as *Pisidium milium* f. *unioides* will very likely be found in additional Boreal or later deposits in other parts of Fennoscandia. I am inclined to suggest that these species are not so cold-stenothermal as generally believed. Further investigations on their subfossil and present distribution may elucidate this question.

Summary. After exclusion of the species which are too eurythermal to be used as climatological indicators some species remain which suggest that the climate in northern Bohuslän at the end of the Finiglacial period was not more severe than the present one in the Swedish Bergslagen and the Finnish lake district.

SUMMARY

The present paper is an account of an investigation of 11 Quaternary shell-bearing freshwater deposits in northern Bohuslän (northernmost part of the Swedish west coast). The sediments were accumulated in small lakes and ponds. The deposits are situated within the range of 65–118 m above the sea. One of them is entirely Finiglacial (formed during the retreat of the Ice from the Bergslagen in Middle Sweden to Jämtland), nine shell-bearing strata accumulated during the final part of the Finiglacial and/or the beginning of the Postglacial period, and one somewhat later (just after the A^0 , i. e. in the middle or later part of the Ancyclus period). The datings are based on pollen diagrams.

The precipitation of freshwater calcium carbonate in N. Bohuslän seems to have occurred only during a short period. No later precipitation has been observed though calcareous parent substances were accessible in great quantities.

The shell-bearing sediments are distinguished by a high percentage of calcium carbonate, which originates from Quaternary marine shell-bearing deposits. In the typical case, the percentage of calcium carbonate is highest in the middle of the

shell-bearing strata where the sediment can consist of a pure lake chalk; in the bottom part, the percentage of calcium carbonate is generally exceeded by minerogene fine-particles and in the top section by phytogene substances. The shell-bearing stratum is overlain by a coarse non-calcareous necron mud without shells. Biologically the sediment was especially examined for molluscs and ostracods. Finds of other animals were noted as well as fruits and seeds. Some 20 mollusc species and 10 ostracod species were observed. Remains of a few other animal species and some 40 plant species were also found. The investigation was quantitative and the frequency is, where possible, illustrated graphically.

Mainly the same mollusc species are generally represented in all the deposits investigated. The highest frequency was attained during the later stage of the small lakes. Most of the species very soon invaded the new lakes and continued to live there until the lakes began to disappear. These species may be very indifferent in ecological respects. A few other species, which mostly migrated later, did not cause greater changes in their frequency. The fluctuations in the frequency of the molluscs are irregular to a great extent and were apparently more or less accidental. It is not possible to trace the reason for the fluctuations; they seem to have been brought about during a continuous competition among the specimens within these small vital areas which could provide for a large but limited number of organisms.

The ostracods had the greatest frequency during the later part of the ancient lakes, probably owing to a good supply of food (vegetative components and dead mollusc bodies were abundant). In other ecological respects, the ostracods considered are apparently rather indifferent.

The aim of my investigation into the plant life of the ancient lakes was, above all, to obtain a knowledge of the surroundings where the shell-bearing organisms lived. The most distinguishing plants were Charophytes and *Potamogeton* species. Some of the species are characteristic of eutrophic waters with good supply of calcium carbonate. Judging from the flora and the composition of the sediment, the ancient lakes afforded appropriate conditions for molluscs and ostracods.

The representation of some species indicates that the Bohuslän climate at the end of the Finiglacial period cannot have been more severe than the present climate in the Swedish Bergslagen and the Finnish lake district. Further investigations on the thermal demands of freshwater molluscs and ostracods as well as on their Quaternary representation will certainly contribute to the elucidation of the Quaternary climate.

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Ivar Hessland.

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Explanation of plates

Plate I.

Pollen diagrams of the localities investigated.

Plate II.

Klingseröd I.

- Fig. 1. Distribution of particles > 0.5 mm (dashed line) and < 0.5 mm (drawn line).
- Fig. 2. Distribution of calcium carbonate and organogene and minerogene components < 0.5 mm.
- Fig. 3. Frequency of the molluscan shells.
- Fig. 4. Distribution of the molluscan families.
- Fig. 5. Distribution of the species *Gyraulus arcticus*, *Armiger crista*, and *Hippeuthis complanatus*.
- Fig. 6. Distribution of the genus *Pisidium* (drawn line) and *Sphaerium corneum* (dashed line).
- Fig. 7. Distribution of the *Pisidium* species.
- Fig. 8. Distribution of fruits.

Plate III.

Figs. 1–6 Klingseröd II, Figs. 7–12 Kålstad, and Figs. 13–17 Fossane.

Figs. 1, 7, and 13. Distribution of calcium carbonate and organogene and minerogene components < 0.5 mm.

Figs. 2 and 8. Frequency of the molluscan shells.

Figs. 3, 9, and 15. Distribution of the molluscan families.

- Fig. 4. Distribution of the species *Valvata cristata* (drawn line) and *Valvata piscinalis* (dashed line).
 Figs. 5, 11, and 16. Distribution of the species *Gyraulus arcticus*, *Armiger crista*, and *Hippeuthis complanatus*.
 Figs. 6 and 10. Distribution of the *Pisidium* species.
 Fig. 12. Distribution of the characean oospores.
 Fig. 14. Frequency of ostracods (dashed line) and molluscs (drawn line).
 Fig. 17. Distribution of the genus *Pisidium* (drawn line) and *Sphaerium corneum* (dashed line).

Plate IV.

- a. *Herpetocypris reptans* (BAIRD)
- b. *Iliocypris gibba* (RAMDOHR)
- c. *Iliocyrella bradyi* (G. O. SARS)
- d. *Cyprideis littoralis* (BRADY)
- e. *Heterocypris incongruens* (RAMDOHR)
- f. *Candona* sp.
- g. *Pionocypris vidua* (O. FR. MÜLLER)
- h. *Gyraulus arcticus* BECK 7.5 ×
- i. *Hippeuthis complanatus* DRAPARNAUD 7.5 ×
- j. *Valvata cristata* MÜLLER 7.5 ×
- k. *Armiger crista* (L.) (f. *typica* and f. *naulea*) 7.5 ×.

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Fig. 1 Floghult

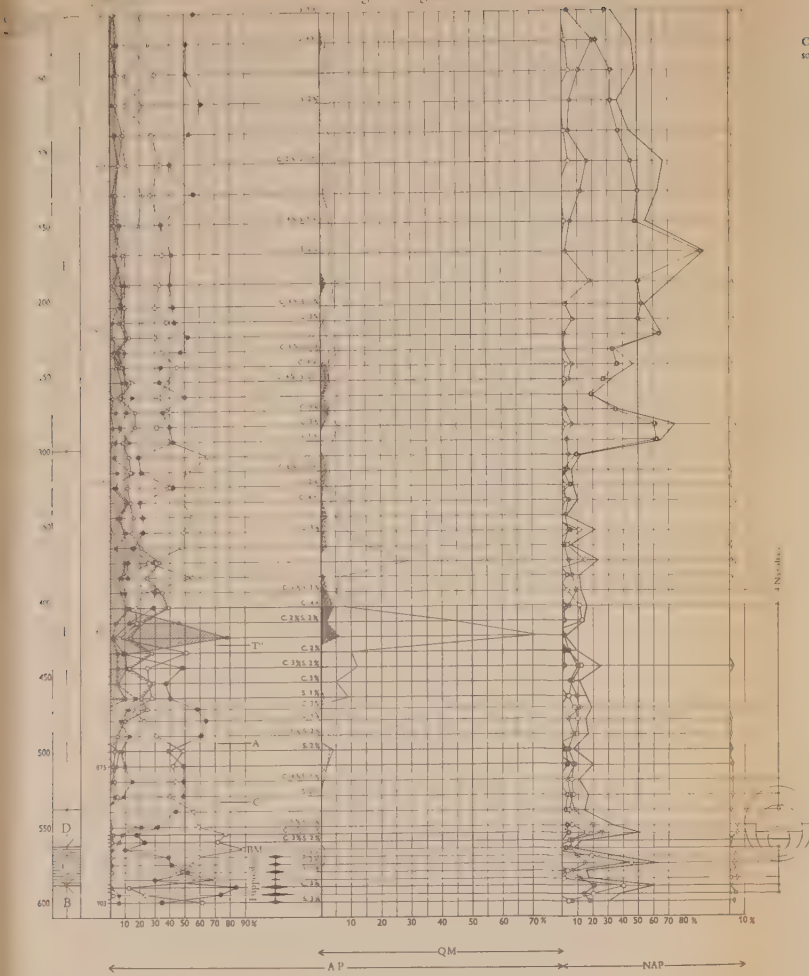


Fig. 2 Askeröd

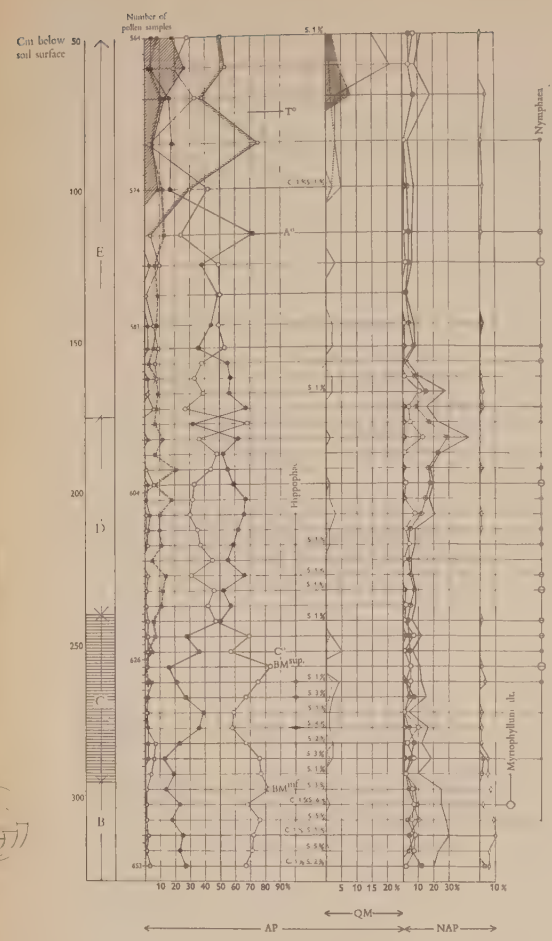


Fig. 3 Klingseröd I

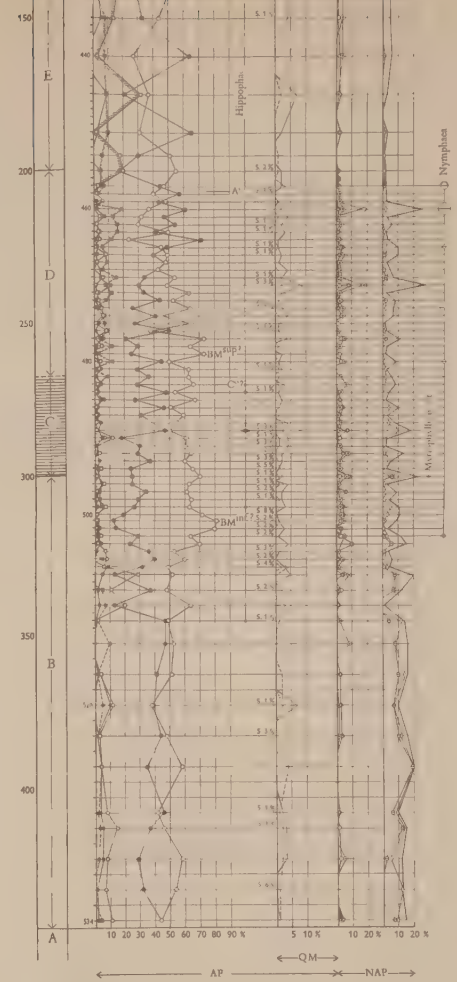


Fig. 4 Kålstad

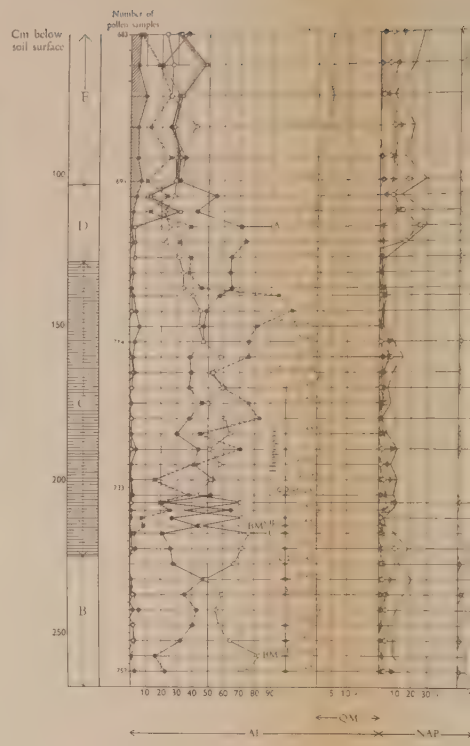


Fig. 5 Rabbalshede

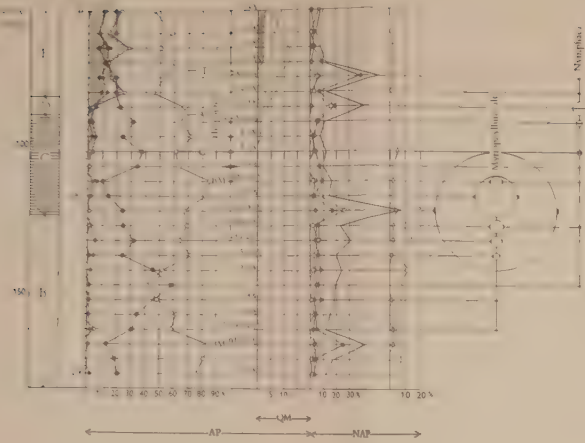


Fig. 6 Klingseröd II

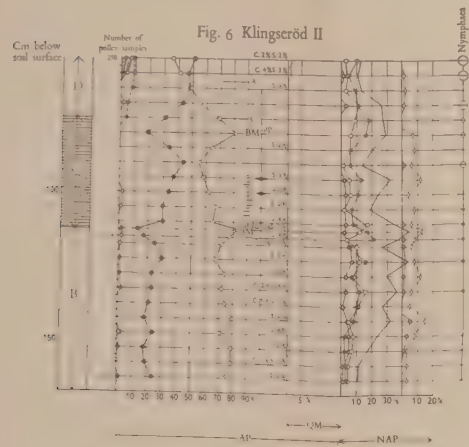


Fig. 7 Branstaby

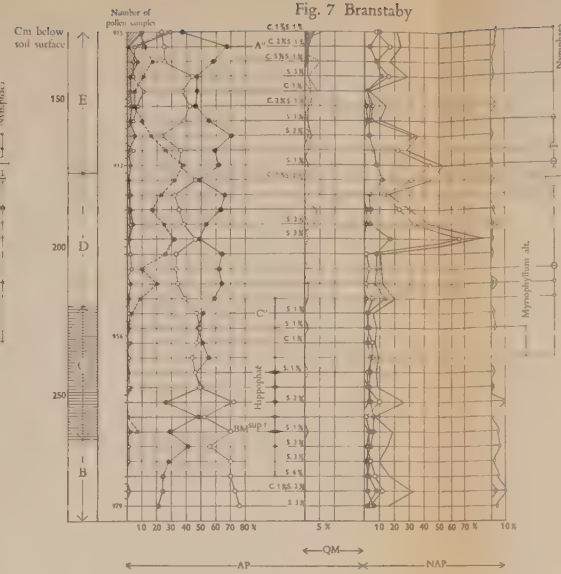


Fig. 8 Stuvängen

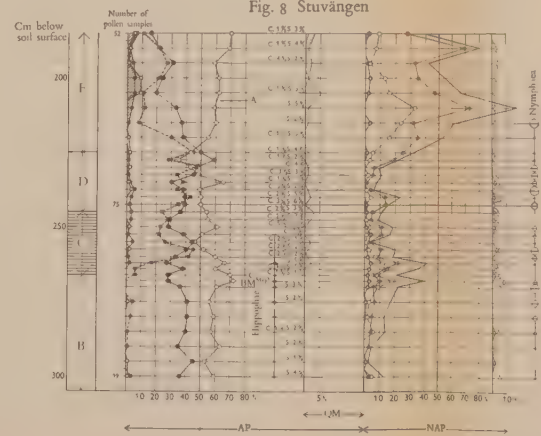


Fig. 9 Hjelpeden

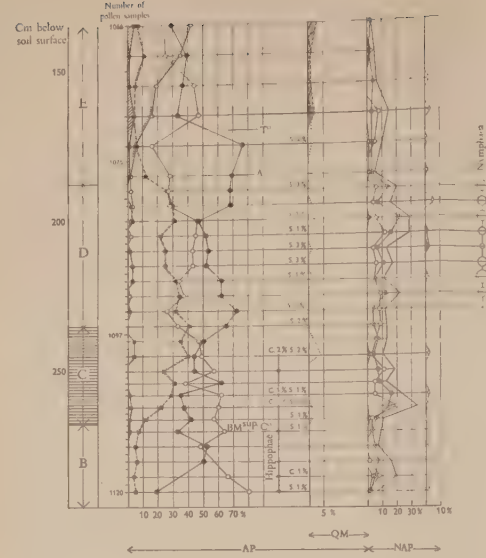


Fig. 10 Fossane

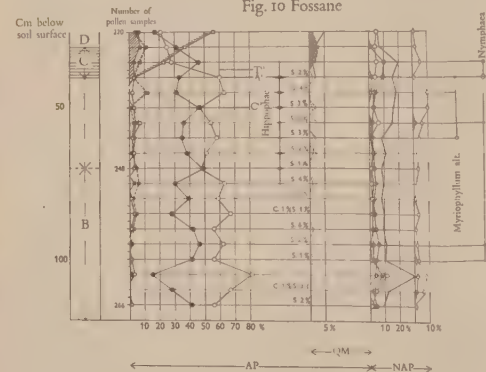
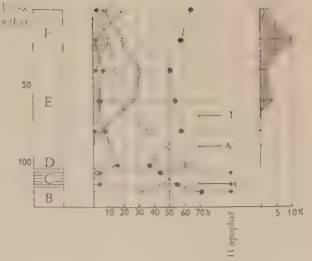
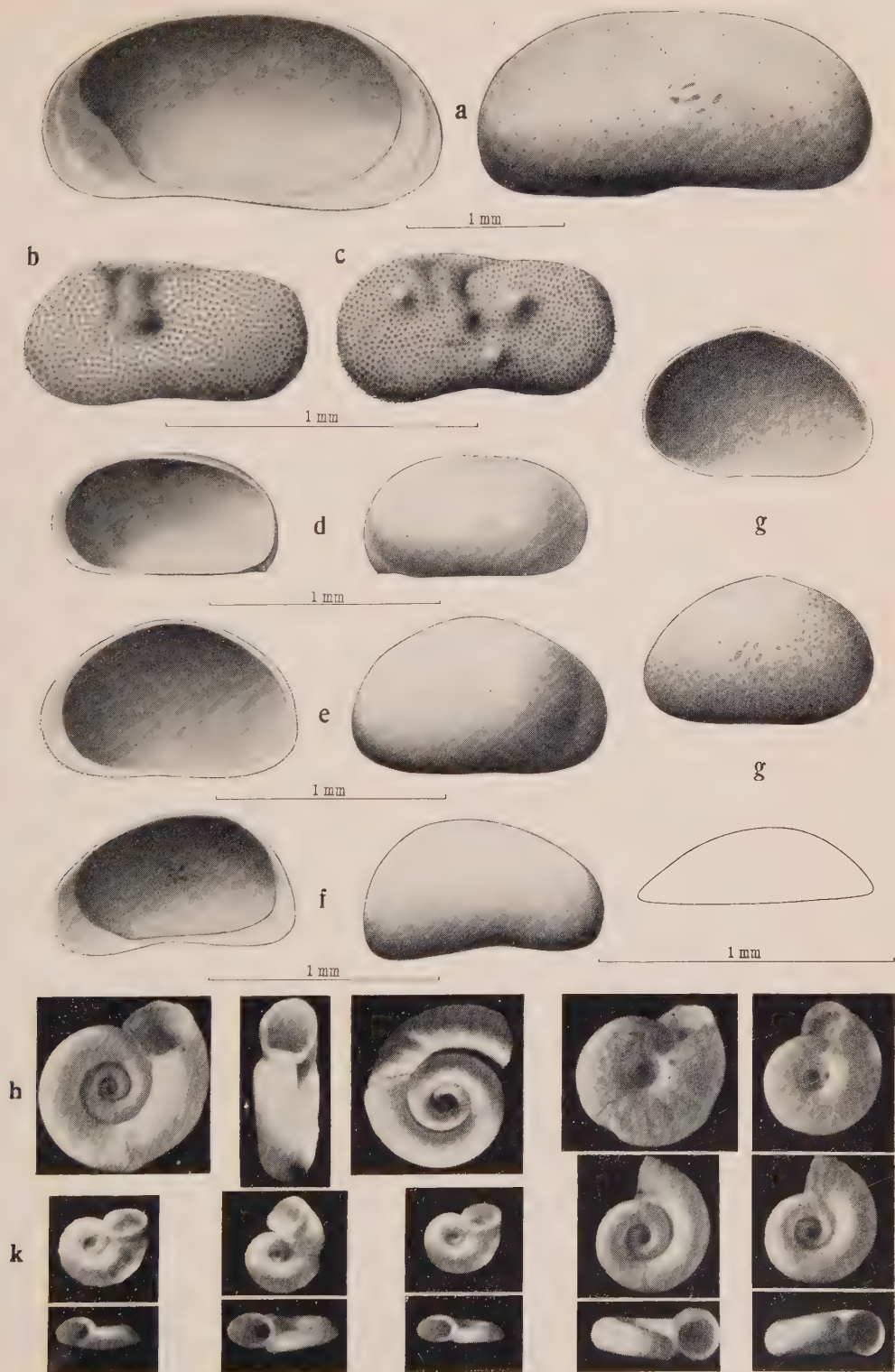


Fig. 11 Korndalen



SYMBOLS

- B Marine clay
- C Shell-bearing freshwater stratum
- D Coarse non-calcareous necrom mud
- E Deciduous fern-wood peat
- F Sphagnum peat
- o Alnus (hatched section of the curve referable to the part above the A")
- Betula
- BM^{UP} Upper Betula max
- BM^{LOW} Lower Betula max
- c Carpinus
- Corylus (hatched section of the curve referable to the part above the C")
- Picea
- Pinus
- Quercetum mixtum (hatched section referable to the continuous part of the curve)
- Quercus
- Tilia (hatched section of the curve referable to the part above the T")
- Ulmus
- S Salix
- Hippoglossum (breadth scale identical with AP scale)
- Ericales
- Gramineae
- Cyperaceae
- Artemisia
- Terrestrial herbs
- Σ NAP
- Nymphaea alba (breadth scale identical with AP scale)
- Myriophyllum alterniflorum (breadth scale identical with AP scale)



A Quaternary diatom spectrum from Bohuslän

By Å. BERG and I. HESSLAND

With 3 plates and 2 figures in the text

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Introduction

In the northern part of the province of Bohuslän on the Swedish west coast there are several Quaternary freshwater deposits with calcareous sediments. Those known at present (11 in number) were described by HESSLAND 1949¹, especially with regard to biogene components; however, diatoms were not considered. This group was intended to be examined separately on a later occasion.

As far as I know, special diatomologic investigations of Swedish Quaternary calcareous freshwater deposits have not been performed. Quaternary freshwater diatoms of N. Bohuslän are, on the whole, fairly little known.

The present investigation may thus contribute to the knowledge both of the sub-fossil diatom flora of this district and of the type of flora in lakes where calcareous ooze and lake chalk are formed. There is, moreover, a particular reason for making an examination of this kind. As observed during my aforementioned investigation,

¹ K. Svenska Vet. Ak. Arkiv för mineralogi och geologi, Bd 1, No. 5.

shells of minute marine organisms (foraminifera and ostracods) and fragments of larger marine shells (prisms of *Mytilus edulis* especially) appear in the calcareous freshwater layers, particularly in the bottom part. Like the freshwater calcium carbonate of the mud, they are derived from Quaternary marine shell-bearing deposits. It would be of interest to ascertain whether marine diatoms, likewise, occur in the calcareous freshwater layers. They are small and easily redepositable, so that they may be expected to be found there.

The diatomist Mr. Å. BERG graciously made a quantitative investigation of the diatoms throughout such a stratum and in the adjacent parts of the underlying marine clay and the overlying non-calcareous necron mud.

This investigation has shown that the calcareous freshwater layer is very rich in diatoms. This is also the case with the examined part of the marine clay. It was observed that marine diatoms occur in the lacustrine layers. In addition, several interesting ecological data have come to light. Many of the marine types are of importance as climatological indicators.

Uppsala, Febr., 1949.

Ivar Hessland.

Description of the locality

The locality investigated is situated at the Kålstad farm about 4.8 km N 45° E from the Tanum church.

The bedrock of this region consists of mainly granitic plateaus separated from one another by generally narrow valleys running in NE-SW and NW-SE directions. For the most part, the plateaus are not covered with sediments; but glacial and marine as well as supramarine Quaternary deposits occur in the valleys.

The Kålstad deposit is situated in the cross-point of a NE-SW and a NW-SE valley, where the morainic matter constitutes a small and shallow basin. A pond was formed here when the basin was separated from the sea during the course of the general land-rise. Calcareous mud soon began to accumulate. The content of calcium carbonate gradually increased, so that the sediment consists of a very pure lake chalk in the middle of the calcareous stratum (which is 60—95 cm thick). However, the content of calcium carbonate decreases rapidly towards the top of the layer which is overlain by non-calcareous plant necron mud.

Details with regard to the composition of the sediment and the distribution of the fossils are given in the above-mentioned paper by HESSLAND 1949. The calcareous layer is very rich in shells, especially of molluscs. The shell frequency is greatest in the upper part.

Among the mussels, *Pisidium* species are abundant throughout the stratum. The following species were observed:

- P. nitidum* JENYNS
- P. milium* HELD
- P. hibernicum* WESTERLUND
- P. subtruncatum* MALM
- P. obtusale* PFEIFFER
- P. lilljeborgi* CLESSIN

Another mussel species present is *Sphaerium corneum* (L.), which, however, occurs in small numbers.

The most abundant species among the gastropods is *Lymnaea ovata* (DRAPARNAUD) which appears with a considerable individual variation (types varying both towards f. *peregra* MÜLLER and f. *lagotis* SCHRANK). A few shells of *Lymnaea auricularia* (L.) were also observed.

The Valvatidae family is represented exclusively by *Valvata cristata* MÜLLER which, however, is numerous.

Among the three Planorbidae species occurring in this deposit *Armiger crista* (L.) (appearing as f. *typica* [DRAPARNAUD] and f. *nautilea* [L.]) and *Gyraulus arcticus* BECK are abundant; the third species, *Hippeuthis complanatus* DRAPARNAUD, is, on the other hand, fairly rare.

Physa fontinalis (L.) and *Acroloxus lacustris* (L.) are also rare.

Ostracods are represented by carapaces and valves of the genus *Candona*.

The vegetation was characterized by Charophytes, judging from the fact that oospores (as a rule encrusted with calcium carbonate) occur throughout the stratum (maximum in the upper part).

The type of flora indicates that the ancient pond was eutrophic and that the water was inconsiderably agitated. Such surroundings are, in our day, favourable for molluscan life, and this was obviously also the case in this ancient pond.

The underlying marine clay is rich in molluscs; no less than 52 species were observed. Four species of Cirripedia were found. These marine species are:

Amphineura

Tonicella marmorea (FABRICIUS)

— *rubra* (LOWE)

Gastropoda

Diotocardia

Acmaea rubella (FABRICIUS)

— *virginea* (MÜLLER)

Lepeta coeca (MÜLLER)

Puncturella noachina (LINNÉ)

? *Propitidium ancyloide* FORBES

Gibbula cineraria (LINNÉ)

Margarites helicina (FABRICIUS)

— *groenlandica* (CHEMNITZ)

— *cinerea* (COUTHOUY)

Monotocardia

Moelleria costulata (MÖLLER)

Natica clausa BRODERIP & SOWERBY

Lunatia pallida (BRODERIP & SOWERBY)

Littorina littorea (LINNÉ)

— *obtusata* (LINNÉ)

— *palliata* (SAY)

— *rudis* (MATON)

Lacuna divaricata (FABRICIUS)

Trophon truncatus (STRÖM)

— *clathratus* (LINNÉ)

Buccinum undatum LINNÉ

Bela bicarinata (COUTHOUY)

— *rugulata* TROSCHEL

var. *scalaroides* G. O. SARS

Onoba striata (MONTAGU)

Hydrobia ulvae (PENNANT)

Rissoa interrupta (ADAMS)

Skenea planorbis (FABRICIUS)

Homalogyra atomus (PHILIPPI)

Opisthobranchia

Retusa nitidula (LOVÉN)

— *truncatula* (BRUGUIÈRE)

Lamellibranchiata

Anomia squamula LINNÉ

Pecten islandicus MÜLLER

Mytilus edulis LINNÉ

Modiola modiolus (LINNÉ)

Astarte borealis (CHEMNITZ)

— *banksi* MÖLLER

— *elliptica* (BROWN)

Thyasira flexuosa (MONTAGU)

— *gouldii* PHILIPPI

Montacuta bidentata (MONTAGU)

Cardium echinatum LINNÉ

— *edule* LINNÉ

— *exiguum* GMELIN

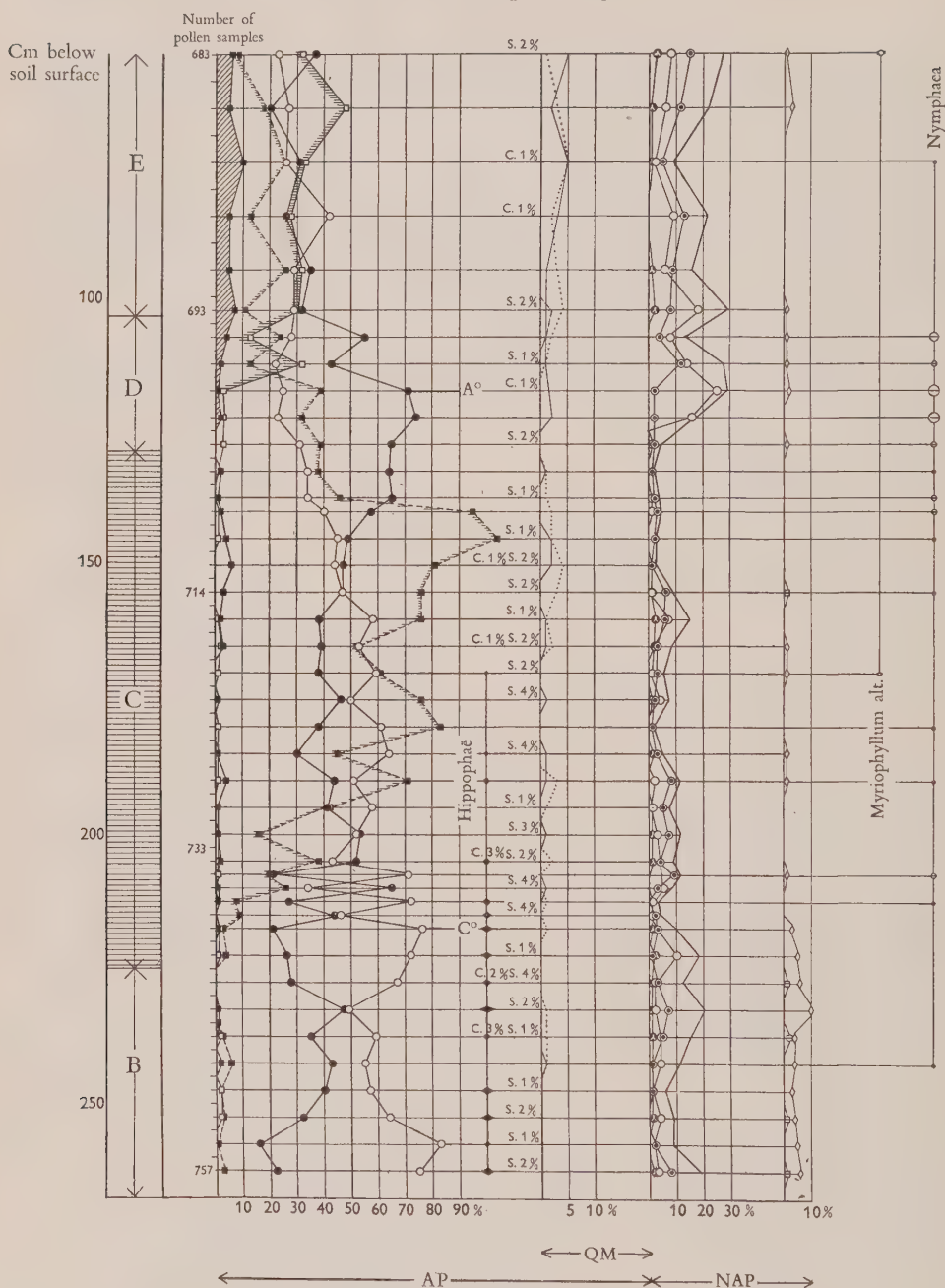


Fig. 1. Kålstad.

Stratal sequence and pollen diagram. B Marine clay. C Calcareous freshwater layer. D Non-calcareous plant necron mud. E Deciduous fen-wood peat. Conventional pollen symbols; concerning NAP pollen: \blacktriangle Ericales, \odot Gramineae, \circ Cyperaceae, \boxplus *Artemisia*, \diamond Terrestrial herbs; the drawn line in the NAP section indicates the Σ NAP. Analyst ULLA JOSEPHSON.

Cyprina islandica (LINNÉ)*Venus gallina* LINNÉ*Macoma baltica* (LINNÉ)— *calcareo* (CHEMNITZ)*Syndosmya alba* (WOOD)— — *nitida* (MÜLLER)*Saxicava arctica* (LINNÉ)*Mya truncata* LINNÉ— — var. *uddevallensis* (HANCOCK)*Cirripedia**Balanus balanus* (LINNÉ)*Balanus balanoides* (LINNÉ) BRUGUIÈRE*Balanus crenatus* BRUGUIÈRE*Verruca stroemia* (MÜLLER) SCHUMACHER

70% of the species are Arctic-Boreal, 20% low-Boreal and Lusitanian; 10% occur at the present day in all these regions.

Among *Mya truncata* f. *typica* there are both thick and thin shells. The former represent a more northern type than the latter. Valves of this species were found in situ, i. e. with the truncate end upwards. The brown cuticle remains and, in some specimens, even the siphonal cuticle is left, which is most remarkable.

Measurements of a great number of specimens from this necrocoenosis showed that the ratios of dimensional data do not form separate groups when plotted in a coordinate system. This fact and the circumstance that the shells form a continuous series with regard to the shape indicate that there is no specific difference among the different types. In fact, they constitute one species with a wide variation.

Modiola modiolus appears with very large shells (150—167 mm length).

Saxicava arctica is fairly large-sized; the majority of the specimens fall within the length limits of 25–40 mm (maximum 50 mm). A thin bed in the clay is formed mainly by *Saxicava* shells.

The barnacles also constitute beds (two in number). The lower of them includes very large specimens of *Balanus balanus* joined to colonies.

The age of the deposit

The dating was made by means of pollen analysis; pollen diagram in Fig. 1.

The pond was formed somewhat previously to the C^o and an upper *Betula* maximum and somewhat after a lower *Betula* maximum which may correspond to the *BM* acc. to v. POST (cf. HESSLAND 1949, p. 109). The formation of the calcareous sediment thus began at the transition between the Finiglacial and the Postglacial periods. It continued for some centuries and ceased somewhat earlier than about 6300 B. C. (the beginning of the continuous *Alnus* curve). The great Boreal hazel maximum was developed during the life-time of the pond.

The diatom flora

Introduction

A series of bore-samples through a Quaternary stratum at Kålstad, Tanum parish, consigned to me by Dr. IVAR HESSLAND for analyses of its diatom content, revealed many features of interest, which are accounted for in this paper. The results are presented without attempt to generalize on the basis of this single series of samples. The investigation is exhaustive and quantitative; this method resulted, inter alia,

in that three vertical diatomologic zones could be distinguished in the calcareous stratum.

The graphic representation was prepared without grouping of the species in accordance with the present knowledge of their ecology. A special chapter is devoted to taxonomic discussions.

A result of special interest appeared, viz. that marine forms occur sporadically throughout the whole lacustrine stratal sequence.

1. Remarks on the laboratory investigation. Presentation of results

The marine strata on our western coast have been investigated for diatoms to a less extent than corresponding sediments in many other parts of the country. However, HALDEN (in 1921 and 1929) thoroughly examined some localities in the province of Halland. In the first of these papers he gives a survey of the previous investigations in the ecology of the marine and brackish-water forms. Since then the importance of complete analyses has become more necessary.

The value of such investigations depends mainly on two factors: an extensive knowledge of recent floras in different habitats, which knowledge is as yet rather incomplete; and furthermore, that no components are lost during laboratory treatment.

The samples should not be allowed to dry up and harden, but should be kept moist in short, wide glass-tubes (e. g. 60×22 mm).

Concerning the treatment of the material, HUSTEDT recommends (1948 p. 183) a procedure, which seems to be very suitable for maintaining all the components of the sample: the dried material is placed in some water with a few drops of hydrogen peroxide; without heating this is generally sufficient for the disintegration of material containing no organic matter. The sample has then to be washed in distilled water. Samples with a small amount of organic matter should be boiled briefly before washing. My own experience confirms that ammonia should not be used. In order to check the results I tried some different methods (cf. below).

The treatment begins with removal of the lime by means of dilute hydrochloric acid, washing and centrifuging. The clays investigated here which contain fairly small quantities of organic matter, are boiled in concentrated hydrogen peroxide as mentioned above. The time of boiling is proportional to the quantity of organic matter. However, the method (in spite of prolonged boiling) did not prove to be sufficient for disintegration of samples which consisted of organic matter to a larger extent. In these cases sulphuric acid with addition of potassium nitrate in the final phase was used. Comparative examinations indicated that even the most minute diatom valves do not seem to have been acted upon. The diatoms were, however, rather corroded already before the treatment and thus not perfectly suited for investigations of this kind. But the lists of the forms were practically identical in both cases, and, therefore, I abandoned the hydrogen peroxide method, inasmuch as sulphuric acid is an agency far more active in dissolving organic matter. I believe though not yet able to prove it — that a prolonged boiling in hydrogen peroxide is more disastrous to the diatom valves than the treatment in sulphuric acid.

After this treatment, according to HUSTEDT (1948, p. 183) the diatoms are left to settle, whereupon "the quite clear acid" is poured off as completely as possible. This, however, seems to be an unsuitable method, since the liquid poured off may contain diatoms which are thus lost. I have found that diatoms and diatom splinters

can be present in the liquid after a long time. For this reason it is necessary to diminish the density of the liquid by adding plenty of water before decantation. To be sure, the time of settling should be sufficient (in the present case no less than six hours, after which the liquid proved to be free from diatoms).

HUSTEDT (l. c.), while pleading for extremely thorough examinations of the types occurring in the material, especially with regard to their first appearance in a stratal sequence, considers exact quantitative analyses of minor importance (l. c. p. 187). Consequently he desists from any graphic representation; he estimates the frequency and gives it by symbols of the types sh and +.

In my opinion, however, it seems desirable to state the exact frequency as far as possible, and moreover, to plot the results graphically. Such a representation is indispensable when interpreting vertical changes of the composition of the flora in sequences of strata.

The present investigation was conducted in accordance with these principles.

The material. The sample was examined at every 5 centimeters, but with greater intervals, however, at the upper and lower limits. The uppermost sample has the number 664, the lowest 790. A total of 29 analyses were made.

From the bottom sample 790 upward to 742 the material consists of marine clay, strongly reacting to dilute hydrochloric acid. 48 marine forms cease to occur at level 744; at 742, 11 more; and at 740, the main group of them, i. e. 85 forms.

At level 742 the material changes over to a calcareous fresh-water mud, but is fairly unchanged with respect to macroscopic conditions and diatom flora. It continues up to and includes level 706, where the demarcation against an overlying stratum of coarse detritus (fresh-water mud, not reacting to hydrochloric acid) is fairly distinct.

Especially in the upper section of the mud (levels 706–710) the diatoms are partly intact and not corroded, partly crushed and more or less corroded. Among the most abundant forms, *Epithemia* (above all *E. Muellerii*) corroded specimens are very common, but in addition to them there is a small number of well preserved ones apparently of a later date. All the *Cyclotella* specimens are in a very bad state; only the resistant middle section remains, and the original pores or striae have been dilated to form open areas. In order to give an idea of the state of the material a similar form is figured here (Pl. II: 1 a, b). The thin, linear forms, *Synedra* or *Nitzschia*, are generally found only as short sections. *Cymbella*, as a rule, lacks the ends of the valves, which are rather important for the generic taxonomy. *Mastogloia* seldom or never shows the thin loculi-membranes. The assumption that an essential part of the flora has entered here secondarily from some considerably older stratum cannot be avoided.

The uppermost stratum, referred to above as a non-calcareous fresh-water detritus, contained a diatom flora poor in both forms and individuals. Like the very numerous resting spores, the diatom valves were strongly crushed. Of the large *Pinnularia*-forms, only the coarse central nodes remain, which are insufficient for specific determination.

Also the valve fragments here were in general badly preserved, with the exception of two forms: *Pinnularia borealis* and *Hantzschia amphioxys*, and possibly a few more. Since the locality at the time of the formation of this layer had long before been cut off from the open sea and consequently from every influence of the surge of the water or motion of ice, the state of the valves possibly indicates that they were partly redeposited. This is obvious concerning a number of marine forms, fragments

of which were found, especially in the uppermost level, 694. These fragments are referable to underterminable *Triceratium*-, *Coscinodiscus*- and marine *Surirella*-forms. A complete specimen of *Pyxidicula lasica* ROTPL. (upper Cretaceous) and a fragment of *Eupodiscus argus*, are, likewise, obviously of foreign origin.

2. Vertical distribution of the forms

The marine clay

The deepest levels investigated, 790 and 780, exhibit typical *Rhabdonema* formations with a relatively insignificant share of coastal plankton. Among the epiphytes, *Rhabd. arcuatum* and *minutum*, *Biddulphia aurita*, *Grammatophora* spp., and *Hyalodiscus scoticus* dominate. A great number of forms are less frequent, such as *Plagiogramma stauroph.*, *Achnanthes polaris*, *Trachyneis asper*, *Navicula abrupta*, *distans*, *Grevillei*, and *Synedra affinis*. A group of species is represented by single specimens, more or less clearly belonging to the association. The planktons are represented by some species of *Coscinodiscus*, *C. angustelineatus*, *curvatulus*, *decipiens*, *oculus-iridis*, *radiatus* in addition to insignificant numbers of *Paralia*. The absence of several of the most common planktonic genera, e. g. *Chaetoceros*, is striking.

The nearest overlying stratum, comprising levels 770-749, includes a stable association, sharply delimited by the over- and underlying strata. The deep water forms *Diploneis fusca* and *Smithii* are strongly dominant; a few others occur with lower frequency, such as *D. chersonensis*, *didyma*, and *litoralis*. Among the epiphytes are *Biddulphia aurita*, *Grammatophora* and *Cocconeis scutellum* var. The demarcation against the underlying stratum appears particularly distinct through the fact that *Rhabdonema* disappears practically completely and is replaced by the *Diploneis*-forms mentioned. *Paralia* is also entirely missing, but returns, strange to say, at a higher level. The genera *Nitzschia* (*acuminata*, *constricta* v. *parva*, *hungarica*, *incurva*, *punctata*, *sigma*, *socialis*), and *Amphora* (*arenicola*, *proteus*, *pusilla*) begin here to appear more abundantly. The upper part of the stratum is characterized by a greater occurrence of marine *Synedra*- and *Caloneis*-forms, besides of which *Diploneis didyma* shows some increase, preceding a later maximum.

The uppermost part of the marine clay, levels 746-744 is distinguished partly by a sudden mass-appearance of *Paralia* (at level 744, thus immediately prior to the separation from the sea), partly by a strong increase of the *Navicula-Nitzschia-Amphora* association indicated by HALDEN (1921) as sublittoral. It is interesting to note that of the 22 forms enumerated by HALDEN as being typical, 13, or 60% were found in our material. In all 115 taxonomic units were observed in this level which is more than in the other levels. Among the epiphytes occur small numbers of *Rhabdonema*, *Grammatophora*, *Dimerogramma*, *Synedra affinis* and *crystallina*, and *Achnanthes polaris* and *brevipes*. *Diploneis didyma* (with a weak admixture of *D. interrupta*) which may be referred to the epiphytes, occurs abundantly. Among the bottom forms the following may be noted: *Scoliopleura tumida*, *Oestrupia blanda*, *Navicula* I and II (cf. list in the explanation of Pl. I), *Nitzschia commutata* and others, *acuminata* and others and *Amphora arenicola* and others. The flourishing vegetation of *Diploneis* (*fusca*, *Smithii* and others), as manifested in the underlying layer, has disappeared almost completely; as mentioned, it was replaced mainly by *Paralia*. All of these, including *Paralia*, could be classified as vagile benthonic forms.

The upper limit of the following forms occurs at level 744 (or, in a few cases, already just before):

Amphora arenicola, *Amphiprora paludosa*, *Biddulphia aurita*, *Caloneis brevis*, *C. formosa*, *C. liber* v. *genuina*, *Cocconeis costata* and varr., *Coscinodiscus anguste-lineatus*, *C. curvatulus* v. *minor*, *C. decipiens*, *C. excentricus*, *Diploneis litoralis*, *D. Smithii*, *Grammatophora* spp., *Hantzschia marina*, *Hyalodiscus stelliger*, *Melosira lineata*, *Navicula abrupta*, *N. distans*, *N. forcipata* v. *densestriata* with f: a, *N. Hennedyii*, *N. peregrina* v. *meniscus*, *Nitzschia constricta* v. *parva*, *N. incurva*, *N. sigma*, *N. socialis*, *N. tryblionella* v. *debilis*, *Paralia sulcata* v. *biseriata*, *Pinnularia quadratarea*, *Plagiogramma staurophorum*, *Pleurosigma elongatum*, *Rhabdonema arcuatum*, *Rh. minutum*, *Stauroneis salina*, *Tropidoneis maxima*.

Contact zone (levels 742–740)

Level 744 has been fixed as the upper limit of the marine clay, since the marine forms here suddenly retire into second place. 36% of all the 136 forms in the "contact zone" are marine, 6% mesohalobes, 2% halophiles, and 56% fresh-water forms. Thus it seems that the diatom flora changes directly into the lacustrine type, though the marine elements still follow for some time because of redeposition.

Plankton is missing, except for some fairly unimportant occurrences of *Coscinodiscus* and *Chaetoceros* and fragments of some other genera; it is of interest, however, that *Cyclotella antiqua* begins to appear at level 742, to rise to a small maximum of short duration in the chalk mud. Among the epiphytes, *Triceratium antediluvianum* is the most marked of all; here as in the lower part of the lime *gyttja* (mud) it is obviously in a secondary position. The genus *Nitzschia* is represented by a continuation of the mixture of euryhalobe marine and indifferent species, which are grouped as "*N. acuminata* and others" at lower levels. Marine forms of *Synedra* (*crystallina*, *affinis*) and *Cocconeis pediculus* occur at a few percentage of each. Concerning the benthonic forms it is above all apparent that the mass vegetation of *Paralia* has disappeared almost completely. At level 742, the following forms (with a frequency of > 1%) reach their upper limit:

Coscinodiscus radiatus, *Dimerogramma minor*, *Diploneis fusca*, *Gyrosigma acuminatum*, *Hyalodiscus scoticus*, *Navicula gracilis*, *Nitzschia acuminata*, *N. hungarica*, *Oestrupia blanda*, *Paralia sulcata*, f. *coronata*, *Scoliopleura tumida* v. *cruciata*, *Synedra affinis*, *S. crystallina*.

Noteworthy among them is the euryhaline fresh-water form *Gyrosigma acuminatum*.

In the middle part of the contact zone, 740, the abovementioned *Cocconeis pediculus* shows a maximum, whereupon it disappears. Its ecology is somewhat unclear: BOYE PETERSEN (1943, 1946) regards it as indifferent, BUDDE (1930) and SCHULZ (1928) as halophilous, KOLBE (1927) and HUSTEDT (1939) as euryhaline, possibly halophilous. Its occurrence in the present material may possibly indicate that it is halophilous; its complete disappearance after level 740 seems to be accidental. Investigations of similar localities are required to clear this point. — At this level, 740, the following forms, with a frequency > 1%, withdraw:

Achnanthes polaris, *A. brevipes*, *Amphora proteus* with var., *A. pusilla*, *Anomoionis sphaerophora*, *Cocconeis pediculus*, *C. sp.*, *C. scutellum* v. *stauroneiformis*, *Coscinodiscus curvatulus*, *Diploneis interrupta*, *Grammatophora arcuata*, *Mastogloia Braunii*, *Navicula digitoradiata*, *Nitzschia gracilis*, *N. punctata*, *Paralia sulcata* f. *radiosa*, *Scoliopleura tumida*, *Triceratium antediluvianum*.

Among the fresh-water forms apparent within this contact zone is a group of *Epithemia* (*argus* and others). They continue to occur, with varying frequency, through the entire lacustrine period. Like the other dominating form, *Fragilaria construens* v. *subsalina*, they are epiphytes. The appearance of this *Fragilaria* is peculiar, being completely absent in the fresh-water levels 738-716, but after that it again shows a maximum, to which we shall return later.

Simultaneously with the disappearance of the marine forms in the contact zone some fresh-water types and mesohalobes or halophytes appear accidentally. Their frequency is insignificant. The changes in the flora in the transitional zone is illustrated in the following table.

Level	Number of forms with frequencies > 1 %, in p. c.			
	Euhalobes	Mesohalobes	Halophiles	Indifferent
738	8	—	—	92
740	13	4	4	79
742	30	10	13	47
744	90	10	—	—

All the euhalobes at level 738 are made up of *Triceratium antediluvianum*, which, strangely enough, is found only within and in the near vicinity of the contact zone (apart from its occurrence in the uppermost part of our material, where it has been obviously redeposited). The forms occurring exclusively in the contact zone are 39 in number, of which 13 are marine, 7 mesohalobes, 3 halophiles or euryhaline oligohalobes, and 16 indifferent. The frequency of the halophiles is < 1%, however, and only 3 mesohalobes have a frequency > 1%, i. e. *Anomoconeis sphaerophora*, *Mastogloia Braunii* and *Navicula peregrina* v. *meniscus*. The occurrence of these intermediate categories as well as of the sporadic marine forms is certainly referable to the play of accidents to a great extent.

The lacustrine calcareous mud

After the separation from the sea the number of forms decreases strongly for a short period (sample 738). In the middle part of the lacustrine stage a more prolonged but similar decrease in the number of types occurs, which has caused the lacustrine stratum to be divided up into three sections (I-III on the graph). The latter decrease is simultaneous with an optimal occurrence of the *Epithemia Muellerii-Fragilaria* spp. vegetation. Whether competition for nourishment is the primary cause of this development or whether it is referable to other circumstances cannot be decided with certainty. It would be very interesting, however, to investigate more sequences of strata to see whether such a development has any greater scope.

The aforesaid 3 horizons include the following levels: horizon I: 730-736, II: 718-728, III: 706-716. The nearest following beneath, 738, is excluded from this division; as mentioned above, a temporary absolute minimum of the number of forms appears here. This is probably correlated with the mass production of one form, viz. *Mastogloia Smithii* v. *lacustris*; in the remaining part of the chalk mud this form appears in a somewhat weaker frequency. The two other dominants in the chalk mud, *Epithemia Muellerii* and *Fragilaria* spp., have similar maxima, though occurring somewhat later. It is of interest to see, how the rather even frequency of *Masto-*

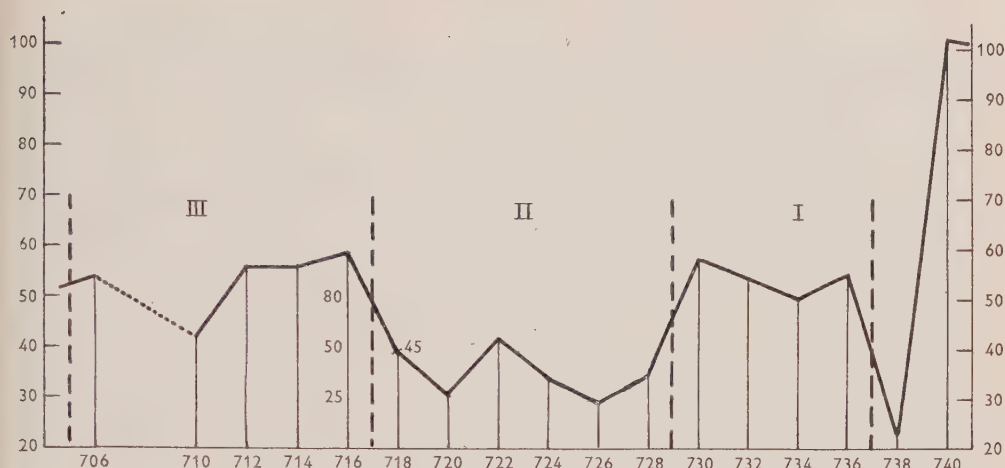


Fig. 2. Number of forms at the levels 706—740.

gloia Smithii v. *lac.* is suddenly broken at level 714, simultaneously with a similar break in the appearance of *Epithemia Muellerii*, and that these breaks are compensated by a mass-production of *Fragilaria* (*pinnata*, and in a lesser degree, *construens* and v. *binodis*).

If the maximum number of forms within the levels belonging here (59 at level 716) is put down as 100, one finds that the corresponding average number of forms within horizon I are 86, II: 38, and III: 86. From the list of the forms (at the end of the paper) we also find the following:

1) Some of the forms appearing within horizon I are completely missing within horizon II, but appear again in horizon III. They are the following:

Caloneis Schumanniana v. *biconstricta*, *Cyclotella Kützingiana*, *Cymbella cesatii*, *C. ventricosa*, *Eunotia tenella*, *Fragilaria constricta* v. *subsalina*, *Gomphonema acuminatum*, *G. acumin.* v. *coronatum*, *G. subclavatum*, *Navicula cari*, *N. mutica*, *Nitzschia amphibia*.

2) Certain forms show their maxima in frequency in horizon II, namely:

Amphora ovalis v. *libyca*, *Cocconeis placentula* and var., *Cymbella Ehrenbergii*, *Epithemia Muellerii*, *Fragilaria construens*, *Navicula radiosa*, *Nitzschia denticula*, *Pinnularia neglecta*.

3) A few forms (with sufficiently high frequency to be taken into account) pass horizon II without showing any decrease in frequency, namely:

Gomphonema intricatum v. *pumila*, *Mastogloia Smithii* v. *lacustris*, *M. coarctata*, *M. streptoraphe*.

The appearance of certain forms within the chalk mud will be more definitely treated in chapter 3.

The non-calcareous coarse detritus

The transition from the rich eutrophic flora in the chalk mud to the so-called trivial acidotrophic flora in the non-calcareous coarse detritus occurs apparently rather abruptly. The forms of the chalk mud flourish in undiminished number right up to the upper limit of the mud.

The dominant genera within the coarse detritus are *Pinnularia*, *Fragilaria*, *Eunotia*, *Tabellaria*, *Hantzschia* (amph.), *Gomphonema*; weakly represented are *Surirella* (*striatula* and spp.), *Synedra*, *Cymbella*, *Diatoma* (elong.), *Navicula* (aerophiles), *Nitzschia* (*parvula*), *Stauroneis*.

Not only the number of forms but also the number of individuals are strikingly small. Sediments of this type can lack diatoms completely; the valves must have been dissolved by agents the nature of which cannot yet be regarded as fully known. KOLBE (1932, p. 274) is of the opinion that "es scheint, dass ein gewisser Zusammenhang zwischen dem Kalk- und SiO₂-Gehalt des Wassers besteht, indem Ca-haltige Gewässer eine stärker lösende Wirkung auf Diatomeenschalen ausüben. Diese Annahme wird bestätigt durch die Tatsache, dass der Grundschlamm der Seen mit höherem Ca-Gehalt nur wenige, zudem stark korrodierte Schalen aufweist." This presumption is, however, contradicted by the fact that the present chalk mud is rich in diatoms; as we have seen, the diatoms are also partly well preserved. A remarkably strong agent of corrosion appeared, however, in the upper part of the chalk mud where, incidentally, the content of calcium carbonate is smaller than in the middle section (cfr HESSLAND 1949 Pl. I and II).

Summary of the diatomological evidences

The marine clay which underlies the lacustrine stratum, was deposited in an arctic sea; this is definitely proved by the occurrence of a number of forms which hitherto have been found exclusively in the Arctic regions. They are the following (quite exact determinations indicated by an asterisk):

**Achnanthes polaris*, **Caloneis brevis* v. *distoma* f. *angustior*, *Chaetoceros groenlandicus*, **Coscinodiscus bathyomphalus*, *C. decrescens* v. *polaris*, *C. sublineatus*, **Navicula solida*, *N. subimpressa*, *Nitzschia insignis* v. *arctica*, *Striatella groenlandica* var.

Only such forms are listed above which have been found exclusively in the Arctic Sea; in addition there is a much greater number which also are found in more southern latitudes.

Among the forms mentioned above the most characteristic, — which are also those which have been marked with an asterisk, — occur even up to the marino-limnic boundary. The so-called contact zone (separation of the lake from the sea at level 743) contains a mechanical mixture of marine and fresh-water diatoms.

The fresh-water diatom flora is distinguished above all by a distinct decrease in the number of forms in the middle section (zone II). The zones I and III are practically identical, indicating similar ecologic conditions in the beginning and at the end of the life-time of the lake.

It is very interesting to note that fragments of marine diatoms occur sporadically throughout the lacustrine stratum, viz. *Triceratium* sp., *Mastogloia Braunii*, *Caloneis brevis*, *Navicula I* and *II*, *Amphora arenicola* etc., *Mastogloia exigua*.

3. Taxonomic and ecological observations

A small number of new or diverging types have been found. In addition to these, however, a considerable number of forms occur, perhaps 10% of the total, which could not be identified with sufficient reliability because of their condition. They have not been treated here, chiefly since the splinters may have been exposed to physical and chemical influences, which preclude any judgment.

Achnanthes polaris ÖSTRUP (1895 fig. VII: 86). **Pl. II: 2.** CLEVE (1896 fig. I: 5) presents a more adequate illustration of the type than did ÖSTRUP. ÖSTRUP's diagnosis: dim. 50×8 ; str. 10 on both valves; locality, East-Greenland on $68^{\circ}25'$ N. CLEVE also states the frequency of striae as 10; locality, Baffins Bay. The specimens at hand: dim. $30 \times 8 - 60 \times 12$; striae 12-13 on both valves. Found in the marine clay with maximum at levels 744-750.

Amphora ovalis Kz., occurring in a low but even frequency in zone 706-730, is represented by a large form with a length of about 100μ , with a frequency of striae of 9 and with a narrow, keeled hyaline line at about the middle of headside of valve. Without knowledge of the locality it would surely have been recorded as "*mexicana*" in spite of the straight raphe.

Amphora ovalis var. *libyca* (EHRB.) CL. The type pictured in **Pl. II: 3** is rather plentiful in the uppermost parts of the lime-gyttja. In spite of the very striking shape of the hyaline areas it must be placed within sphere of the var. *libyca*-forms.

Amphora sp. I at level 770. **Pl. II: 4.** Valve semi-elliptic with slightly declined capitate ends; dim. 42×9 , striae 7, coarse, apparently without structure, but divided in the middle by a hyaline line. Raphe straight, near ventral line; no areas on its upper side. No structure on the ventral border.

Amphora sp. II, at level 770. **Pl. II: 5.** Dorsal line strongly arcuate, the ends inconspicuously rostrate. Dim. 30×9 , striae 7, coarse, apparently without structure. Raphe straight, near ventral line; no areas on the dorsal side. At ventral line a row of pearls, frequency 9. Zonal side complex with numerous rows of pearls. Possibly this is identical with *Amphora* sp. I.

A rich flora of *Amphora*-types occurs at levels 718-750. The marine forms may be regarded as belonging chiefly to the *proteus*-group, the fresh-water types to the very variable *libyca*-group; hardly ever were two perfectly identical specimens found. They were drawn but are not reproduced, since space does not permit dealing with these intricate forms here.

Caloneis formosa (GREV.) CL. var. *holmiensis* CL.? (CL. 1881 p. 8 fig. II: 18). **Pl. II: 6.** CLEVE's diagnosis: dim. $70-100 \times 23$; str. 12.5, slightly radiating, imperceptibly punctate; in brackish water, Vaxholm. — Some few specimens were found at level 706, i. e. in the uppermost lime-gyttja bed. Dimensions $60 \times 11 - 87 \times 13.5$; str. 15-16 with a conspicuous narrow fenster-band near the middle of the striae. Margins more parallel than in CLEVE's specimens; the area (with marked, very narrow necks towards apices) gets its shape through the striae being all of equal length. Raphe broad and straight. The present type occurs among large *Caloneis*-forms from the well-known diatom localities at Cherryfield and Bemis Lake, N. H., U. S. A., and Demerara in Guiana. Some types from Santos in Brazil, described as *Caloneis formosa* by GRUNOW, are in fact intermediate between the marine type and these brevistriated forms. The gen. *Caloneis* is in urgent need of revision, and, therefore, I have not considered it appropriate to give the present type a particular name, though it has rather little to do with *C. formosa* var. *holmiensis*. Of its ecology nothing can be said with certainty; it may have been transported into this place from marine beds in the vicinity.

Caloneis alpestris (GRUN.) CL. **Pl. III: 12.** With a favourable orientation of the valve a distinct longitudinal beam is discernible besides the very narrow lateral fenster-ribbon; its width is half of that of the fenster, and it is situated between the latter and the margin of the valve. Cfr HUSTEDT 1935 p. 13.

Caloneis brevis GREG. f. *constricta* n. f. **Pl. II: 7.** Margins slightly impressed.

Chaetoceros. A number of resting spores occur at the upper levels of the marine clay; having been more or less damaged by corrosion, they cannot be named with certainty. — **Pl. II: 9, 10.**

Cocconeis pediculus EHRB. is found only in the contact zone, but rather plentifully there; then it disappears completely and is replaced by *C. placentula* v. *euglypta*.

Cocconeis sp. **Pl. II: 8.** Valve broadly elliptical; raphe-valve with a narrow inframarginal hyaline stripe. Striae at the margins 16, fine, apparently without structure, crossed by two ribbons of coarse punctae, curved against apices.

Coscinodiscus Hauckii GRUN.? (V. H. Syn. T. 94 fig. 29) **Pl. II: 31**, from level 770; one specimen, rather well preserved. Dim. 24 μ , areoles in the central area in quincunx (which has not been properly brought out in the figure), frequency 12; marginal radiating striae 18, inframarginal short spines 9/10 μ . Valve slightly convex. — The type diverges from *C. Hauckii* in the arrangement of the areoles and by the presence of spines. I have not been able to find again the type in GRUNOW's original stuff from Rovigno, and the question of identity remains open. GRUNOW's figure, reproduced in HUST. 1930 fig. 200 a, in 600: 1, is little enlightening.

Coscinodiscus bathyomphalus CL. **Pl. II: 12**, from the marine clay level 742-770. Dim. 18-30 μ , areoles 12/10 μ . An arctic type, hitherto found at Spitzbergen and in the Arctic Sea.

The determination of the majority of *Coscinodiscus*-types has offered great difficulties because of the state of the valves. Generally the marginal zone was missing. With regard to the types that were more difficult to identify, reservations must be made as to the correctness of names.

Cymbella cistula (HEMPR.) GRUN. var. **Pl. III: 16.** Differs from the species by essentially sparser lineolae, viz. 8 instead of 18-21.

Cymbella Ehrenbergii Kz. f. a, **Pl. III: 14.** A narrow, almost quite symmetrical type, in other respects quite in accordance with the species. Previously I have seen living specimens in Lake Flögen, Småland. The form alternates with the species in the lime-gyttja; possibly the change in shape has something to do with some change in the chemical conditions of the water (cf the variations of *Caloneis amphib.* var. *subsalina*!).

Cymbella sp. A non-identified form is reproduced in **Pl. II: 11.** Dim. 86 \times 11.5; str. 18. From level 749 in the marine clay.

Cyclotella antiqua W. SM., **Pl. II: 1, III: 19**, occurs with varying frequency (max. 3.5%) within zone 732-742, immediately after the isolation from the sea. HUSTEDT (1948 p. 200) considers it "an unmistakable leading type for late glacial calciferous beds", which agrees very well with our case. This does not, however, prevent the same scientist from listing the species as recent in masses from acid habitats (on *Sphagna*) in the Sarek Mountains. The ecology of this species seems to hold several points of interest, which are as yet not fully understood.

Dimerogramma lanceolatum PERAG. (Diat. d. Fr. T. 82: 12). **Pl. II: 13.** Dim. 18-50 \times 9; str. 11-12, coarsely punctated. In the marine caly. "More common in the Mediterranean" (HUST.).

Eunotia sp. **Pl. II: 14.** A splinter from the lime-gyttja, which could not be identified. Striae 9/10 μ , coarse and irregular, of *E. major*-type, with numerous short dorsal striae. Thoroughly known as this genus is nowadays, this form is considered to arouse interest in spite of its imperfect condition.

Eunotia arcus EHRB., the only species known of this genus, which thrives as well in acid as in basic habitats, was subject to an especially careful study here. Dis-

regarding (besides this species) scattered, solitary specimens or traces of *Eunotia*-types down through the whole of this bed, the genus at first occurs, represented by 17 species, at level 700 in the coarse detritus. Here are found at least two types, usually regarded as Boreal, viz. *bactriana* and *polyglyphis*, characteristic forms in recent Laponian dystrophic habitats. *E. arcus*, on the other side, occurs already at level 736, continues on through horizon I (cf. above) at about 1.5%, then decreases somewhat in frequency, but remains nevertheless up through the whole of the sequence. In the uppermost horizon, 694, struggling against the bulk of other *Eunotiae*, *Pinnularia* etc., it still presents a frequency of 1%. Further it has been established here beyond doubt that the forms in the lime-gyttja and in the coarse detritus are identical morphologically. Consequently this species differs from the other members of the genus as to physiological qualities, in some respect as yet unknown. In the material at hand yet some types out of other genera seemingly possess this quality of "eurytopism", viz. *Fragilaria construens* var. *subsalina*, *Gomphonema intricatum*, *Synedra ulna* and the main form of *Pinnularia viridis*. — JÖRGENSEN (1948 p. 52) characterizes *Eunotia arcus* as an "acidophile", optimal at pH = 6–7. Its appearance in our material does not confirm this judgment.

Hantzschia amphioxys (EHRB.) GRUN. is totally missing in the lime-gyttja, but appears at once in the coarse detritus, and from the beginning in a high frequency, 6%. It is known by its capacity to adapt itself to extremely varying ecological circumstances, even as regards the salinity of the habitat. BOYE PETERSEN (1943 p. 75) calls it indifferent, but its appearance here does not indicate indifferentism, more likely "calcifobism", — a term, however, too weakly founded on real knowledge to be used in wider connections; nor in this case ought any conclusions be drawn without further knowledge.

Epithemia Muellerii FRICKE. It is noteworthy that while the other four representatives of the genus occur, and rather richly also, already at level 742, this species is absent until level 738, then appearing at once in a mass-formation, maintained through the whole of this bed. At the upper limit of the lime-gyttja the genus disappears totally.

Mastogloia. Investigating a brackish-water locality in the Baltic, I found that the latest account of the taxonomy of this genus (HUST. 1933) concerning our northern forms, gives a less adequate expression of their real status. This opinion is strengthened even more through our experience of the present material. An inevitable result is that two new names must be proposed for forms, which hardly can be quite new to science.

Mastogloia coarctata n. sp. **Pl. II: 15.** V. broadly lanceolate with ends prolonged and slightly rostrate. Dim. 35×11 – 42×12 ; axial area narrow and somewhat widening toward the middle. Central area small, rounded. Striae 14–16, uniformly radiating, one or a few short ones at the centre; coarsely punctated with ca $13/10 \mu$ in distinct longitudinal lines. Loculi 8–9/10 μ with a height of 3 μ , occupying about half the length of the valve. Raphe-branches distinctly curved.

This species, possibly hitherto called "*elliptica*", occurs with an even spread through the lime-gyttja, levels 706–740. It is a decided fresh-water type.

Mastogloia exigua LEWIS (var. *rostellata* A. CL.-E. 1915?). **Pl. II: 16.** One specimen from level 746 of the marine clay. The identity with the var. mentioned, — a sub-fossil from the White Sea districts — is not indisputable; the latter has prolonged narrow rostra, strictly parallel striae, and no central area at all. Our type agrees better with HUSTEDT's *M. pusilla* var. *subcapitata* from Borneo.

Mastogloia streptoraphe n. sp. **Pl. II: 17.** Margins parallel, ends cuneate and rounded; dim. 45×10 – 80×11 . Axial area unusually broad (29% of the valve); central area a moderately large oval. Striae 15, slightly and uniformly radiating, a few short ones at centre; coarsely punctate (12 – $13/10 \mu$); the arrangement of puncta in longitudinal lines as conspicuous as the transverse lines. Loculi $7/10 \mu$, with a height of 2μ , occupying $2/3$ of the length of the valve. Raphe-branches strongly complex with median arc the longest and highest.

The species occurs as an unimportant but even ingredient through the whole of the lime-gyttja; a decided fresh-water form, like *M. coarctata* in calciferous habitat.

Navicula praecepta n. nom. **Pl. II: 18.** The fragment found at level 740 shows great likeness to "*Navicula bicontracta* ÖSTR." in A. S. Atl. T. 403 fig. 47, 48. Dimensions of the specimen ca 54×9 , str. 7–8, thin (cf. *Pinnularia intermedia*) with a longitudinal line, glistening, and composed of a massive knot on every stria, somewhat looming on both sides of the stria, but not quite coherent with the knots on the adjacent ones.

The determination is based upon the figure 47 in Atlas, which, however, seems to have nothing to do with ÖSTRUP's original form (ÖSTR. 1902 p. 32 fig. 7), except as to outline. The last-named form has 12–13 striae in 10μ , strongly radiating at the centre and one short stria there; ÖSTRUP mentions no longitudinal line, which nevertheless is very conspicuous in the type. This type came from fresh-waters in Siam, and it has manifestly never again been identified. HUSTEDT's determination applies to samples from lakes in Switzerland and Lower Austria, which agree essentially better with the present discovery in a post-glacial bed. The type now at hand is entitled to a name of its own; the form reproduced in Atlas, by HUSTEDT incorrectly called *bicontracta*, must on account of disparities in form and frequency of striae, be classified as a variety of our present form.

Navicula subimpressa GRUN.? **Pl. II: 19** from level 770. — Syn. *Nav. gelida* GRUN. var.? *subimpressa* GRUN, in CLEVE Syn. II p. 29. Arct. Diat. p. 39 fig. II: 45. — Dim. 32×11 ; str. 13, extremely finely lineated. GRUNOW's diagnosis: 65×16 , str. 11–12 finely punctate; Karian Sea. — The accordance is rather good, except that the striae in our specimen are finely lineated (visible in hyrax), which GRUNOW certainly cannot have seen at all, and further that the longitudinal lines, noticed by GRUNOW, are inframarginal, not as in G's specimen placed midmost on the striae.

Navicula torneensis CL. var.? **Pl. II: 21**, from level 749 in the marine clay. Dim. 22×8.5 ; str. 17. CLEVE's diagnosis: dim. 17 – 24×8 – 10 ; str. 14; in brackish-water, G. of Bothnia (CL. 1891 fig. II: 6). The form now at hand may be taken as a variety of *Nav. torneensis*, with striae somewhat denser and a large rectangular central area.

Navicula tuscula (EHRB.) GRUN. var.? **Pl. II: 20**, from level 740. Differs from the type in two respects: the striae are interrupted only by two longitudinal lines, next to the axial area, otherwise uninterrupted; secondly, the striae are equipped with marginal alternating, seemingly semicircular pore-fields, giving the impression of a hyaline zigzag band; these pore-fields recur on the two axial rows of punctae. This arrangement does not correspond to the description in HUST. 1930 p. 308.

Navicula sp. **Pl. II: 22** from level 746. Length 39μ , striae 20, difficult to see, parallel. (*Libellus*?).

Nitzschia insignis W. SM. var. *arctica* GRUN.? **Pl. II: 23** from level 770, marine clay. A badly corroded specimen. Keel-points $2.3/10 \mu$, striae invisible.

Pinnularia borealis EHRB. follows the occurrence of *Hantzschia amphioxys* in detail;

lacking in the lime-gyttja, it appears at once in the coarse detritus in a frequency of 13%. This species too has been characterized as an indifferent eurytope (HUST. 1938), which is indeed correct though the remark I made concerning *Hantzschia* applies also in this case.

Pinnularia neglecta (A. MAYER) Å. BG. Ms. Its occurrence here signifies a welcome contribution to the knowledge of the ecology of this species. I have described the form as corresponding to the North-American *Pinnularia flexuosa*, though smaller and more slender, and identified it in samples from eutrophic localities in Fennoscandia etc. In CLEVE-MÖLLER, Diatoms, no. 32 from Uppsala (Ancyclus?), GRUNOW names it *P. "viridis"*. Common to these habitats is a more or less high lime content, at times perhaps somewhat saline (Landborgen, Öland and Saltkällesjön in Södermanland). In the material at hand this species appears at level 740 and continues through the lime-gyttja to level 706 with a maximum at level 718, but does not occur in the coarse detritus, where all of the other *Pinnulariae* attain their greatest frequency. In ecological character it thus differs strongly from practically all other members of the genus.

Pinnularia viridis (NITZSCH) GREG. The large groups of forms brought together under this name, cannot be expected to give any definite evidence as to ecological standards. The forms present here, among which the *major*-like central type hitherto called var. *intermedia* is represented, are found solitary exactly from level 742 upwards, more abundant, however, only in the upper level of the coarse detritus, level 694.

Rhabdonema minutum Kz. var. *sulcata* FRICKE. Pl. II: 25, from level 744. Previously found only at Novaja Zemlja.

Rhabdonema minutum f. *capitata* n. f. Pl. II: 24, from level 770. Dim. 47×14 ; str. 9. Ends elongated, capitate with narrow necks.

Rhoicosphenia marina (W. SM.) M. SCHMIDT var.? Pl. II: 26, from the marine clay. Dim. 32×12 ; str. 12–13. The main type has 18–24 striae on the convex valve, 15–20 on the raphe-valve. The unusually long raphe-branches as well as the broadly rounded headend indicate nearer kinship to *Rh. marina*.

Scoliopleura tumida (BREB.) RBH.? var. *cruciata* n. var. Pl. II: 28, from levels 742–746. The cell is characterized by its high connecting, deeply striated sides; this shape forces the valves into an oblique position, as shown by the figure. Dim. 60×15 – 75×18 ; str. 15–18, flat, inconspicuously lined, dense. The transverse lining certainly would not be visible at all but for the influence of corroding. Central area forming a rather narrow rectangular space, generally reaching down to the border of the valve (the streaked line in the fig.); at times this area is well-marked only next to the central nodule. — On account of the position of the cells it is difficult to make out the shape of the raphe; from our figure the conclusion might perhaps be drawn that the raphe is in reality slightly sigmoid. — It is above all the habit of the striae which has induced me to bring this form to *Scoliopleura*.

Stauroneis sp. Pl. II: 29 from level 746. Dim. $90 \times ca\ 12$; str. 17, inconspicuous. Valve corroded and defective, yet of certain interest.

Striatella groenlandica ÖSTR. var.? (ÖSTR. 1897 p. 341 fig. II: 16) Pl. II: 30. The frequency of striae in the main form 17, but in our form 30/10 μ .

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Table A & B.

The figures indicate per cents; the figure 0.0 indicates occurrence not counted.

Table A

	694	700	706	710	712	714	716	718	720	722	724	726	728	730	732	734	736	738
<i>Achnanthes Biasolettiana</i> Kz.....	—	—	—	—	—	-1	-2	—	1.2	-4	—	—	—	-4	-3	—	—	—
<i>conspicua</i> A. MAYER.....	—	—	-2	—	-2	-2	-2	-2	-4	—	—	—	—	-3	—	—	—	—
<i>Anomoeoneis serians</i> (BREB.) CL.....	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Amphora ovalis</i> Kz.....	—	—	-2	-7	-2	-5	-5	-2	—	-8	-3	—	-4	-6	—	—	—	—
— var. <i>gracilis</i> (EHRB.) CL.....	—	—	-5	-7	1.8	—	—	—	—	—	—	—	—	—	—	—	—	—
— var. <i>libyca</i> (EHRB.) CL.....	—	—	-7	1.3	-5	-8	1.-	-4	3.8	4.2	2.5	2.-	1.6	2.3	2.1	2.1	2.4	2.9
— — f.a.....	—	—	1.6	2.-	1.4	2.1	—	—	—	—	—	—	—	-3	—	—	—	—
<i>perpusilla</i> GRUN.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>pediculus</i> var. <i>exilis</i> GRUN.....	—	—	-5	-7	1.8	1.9	—	—	—	—	—	—	—	—	—	—	—	—
<i>Caloneis alpestris</i> (GRUN.) CL.....	—	—	-2	—	—	—	—	-2	—	—	—	—	—	-3	—	—	-3	—
<i>bacillum</i> (GRUN.) MERESCHK.....	-5	—	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	-3	—
<i>brevis</i> GREV.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-4	—
<i>formosa</i> GREG. var. <i>holmensis</i> CL.?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	—
<i>liber</i> W. SM. var. <i>eccentrica</i> CL.....	—	—	-4	—	—	—	—	—	—	—	—	—	—	—	—	—	-4	—
<i>Schumanniana</i> (GRUN.) CL. var. <i>bicon-</i>	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	—
<i>stricta</i> GRUN.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cocconeis placentula</i> EHRB.....	—	—	1.4	-7	4.3	-5	-1	—	—	-4	-3	—	—	—	-3	—	-3	—
— var. <i>euglypta</i> (EHRB.) GRUN.....	—	—	—	—	-2	—	-5	-2	-8	-8	-3	-4	—	1.7	-6	-3	-3	-8
— var. <i>klinoraphe</i> GEITL.....	—	—	—	—	—	—	—	—	—	—	—	—	—	7.9	2.-	2.1	—	—
<i>Cyclotella antiqua</i> W. SM.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-0	3.5	-0	-0
<i>comita</i> var. <i>radiosa</i> (EHRB.) Kz.....	—	-7	1.3	2.7	-6	-3	-4	-4	1.2	-4	-3	-8	-4	-6	—	1.-	-3	-0
<i>Kützingeriana</i> THWAITES.....	—	—	—	-7	—	—	—	—	-4	—	—	—	—	-7	—	-3	-3	—
— var. <i>planetophora</i> FRICKE.....	—	—	—	3.9	3.-	—	—	—	-4	—	—	—	—	-6	-6	2.8	3.7	-7
<i>Menequiniana</i> Kz.....	—	—	—	—	—	—	—	—	—	—	—	—	-4	—	—	—	—	—
<i>ocellata</i> PANT.....	—	—	—	—	—	—	-3	—	-4	—	—	—	—	—	-9	2.4	2.4	1.5
<i>stricta</i> (Kz.) GRUN.....	—	—	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cymbatopleura solea</i> (BREB.) W. SM.....	—	—	—	—	—	-1	—	—	—	—	—	—	-1	—	—	-4	—	—
<i>affinis</i> Kz.....	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>aspera</i> (EHRB.) CL.....	—	-7	-7	-2	-5	-7	-2	-2	—	—	—	—	—	—	—	—	—	—
<i>Caesatii</i> (RBH.) GRUN.....	—	—	—	—	-5	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>caespitosa</i> Kz.....	-5	—	—	—	-2	-1	—	—	—	—	—	—	—	—	-3	—	—	—
<i>cistula</i> (HEMPR.) GRUN.....	—	—	—	—	—	—	1.1	-6	—	—	-6	—	—	—	—	-4	—	—
— f.a.....	—	—	—	—	—	—	-2	—	—	—	—	—	—	—	—	—	—	—
<i>cuspidata</i> Kz.....	—	—	—	—	—	—	—	-9	1.2	-4	1.3	1.2	-8	3.7	-9	-3	-4	—
<i>cymbiformis</i> (AG.) V. H.	—	—	1.4	2.-	7.5	2.5	-9	-9	1.2	-4	1.3	1.2	-8	3.7	-9	-3	-4	—

Table A (cont.)

	694	700	706	710	712	714	716	718	720	722	724	726	728	730	732	734	736	738
<i>Cymbella Ehrenbergii</i> Kz.	—	—	—	—	—	-1	1.7	1.3	-4	1.3	11.4	2.3	1.2	-2	-9	-7	1.4	-8
— f.a.	—	—	2.1	1.3	-2	1.5	—	—	—	—	—	—	—	—	—	—	—	—
<i>gracilis</i> (RBH.) CL.	2.-	—	-2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>helvetica</i> Kz f.a.	—	—	1.2	1.3	2.5	-5	-5	—	-8	-4	-6	—	-4	2.-	1.2	-7	2.-	—
<i>incerta</i> GRUN.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>laevis</i> NAEGELI.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>naviculiformis</i> AUERSW.	-5	—	—	—	—	—	—	—	—	—	—	—	—	-3	—	—	3	—
<i>parva</i> (W. SM.) CL.	—	—	—	—	—	—	-5	-6	—	-4	—	-4	—	-8	-3	—	-3	—
<i>prostrata</i> (BERKEL.) CL.	—	—	—	—	—	—	—	—	—	—	—	—	—	-2	-3	-3	—	—
<i>tumida</i> (BEB.) V. H.	—	—	—	—	—	—	—	—	—	—	—	—	—	-8	-3	—	—	—
<i>ventricosa</i> Kz.	-5	-6	-2	-7	-9	-3	-2	—	—	—	—	—	—	-8	-3	—	—	—
<i>Denticula elegans</i> Kz.	—	—	1.4	1.3	3.6	-2	-1	—	—	-4	-9	-8	—	3.1	1.8	2.8	1.	—
<i>Diatoma elongatum</i> Ag. var. <i>tenuis</i> (Ag.) Kz.	—	2.7	—	—	—	—	—	—	—	—	—	—	—	-5	—	—	—	—
<i>Diplotaxis ovalis</i> (HILSE) CL.	—	-7	-2	-6	-5	—	-1	-2	—	-4	—	—	—	—	—	-3	—	—
— var. <i>oblongella</i> (NAEG.) CL.	-5	-7	—	—	—	-2	—	—	—	—	—	—	—	—	—	—	—	—
<i>didyma</i> (EHRB.) CL.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	—
<i>Epithemia argus</i> & var. <i>interned.</i> Kz.	—	—	3.5	-6	1.8	.2	1.4	—	—	-4	—	—	—	—	—	—	—	—
<i>Moellerii</i> FRICKE.	—	-7	28.1	39.4	12.1	2.7	18.6	38.8	21.9	41.1	51.6	43.4	11.5	7.6	13.-	23.-	16.2	7.5
<i>sorex</i> Kz.	—	—	1.6	-6	2.5	1.6	3.-	2.1	1.7	1.7	1.9	1.2	1.6	4.2	.8	-4	1.-	—
<i>turgida</i> (EHRB.) Kz. & var. <i>granulata</i> (EHRB.) GRUN.	—	—	-7	-6	1.8	1.4	-2	—	-4	—	-3	-4	-8	-8	2.-	4.1	3.4	12.6
<i>zebra</i> (EHRB.) Kz.	—	—	—	—	—	—	-1	-4	—	-0	-3	-4	1.2	—	—	-3	-7	.7
<i>Eumothia alpina</i> NAEG.	-5	—	—	—	-2	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>arcus</i> EHRB.	1.-	-6	-7	-0	-7	-2	1.6	-2	-8	-8	-6	-4	-4	1.7	1.5	1.7	1.4	—
<i>bactriana</i> EHRB.	—	1.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>denticulata</i> (BEB.) RBH.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>diadema</i> EHRB.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>exigua-gracilis</i> (GRUN.)	—	-6	—	—	—	—	—	—	—	-4	—	—	—	—	—	—	—	—
<i>Grunovii</i> A. Bg. var. <i>dispersa</i> A. CL.-E.	—	—	—	—	—	—	-2	—	—	-0	—	—	—	—	—	—	—	—
<i>lapponica</i> A. CL.	—	—	—	—	—	—	—	—	—	-0	—	—	—	—	—	—	—	—
<i>major</i> W. SM.	2.-	2.7	—	—	-2	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>monodon</i> EHRB.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>pectinalis</i> (Kz.) RBH.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
— f. <i>minor</i> (Kz.) RBH.	1.-	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-7	—
<i>polyglyphis</i> GRUN.	1.-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>praerupta-minor</i> (EHRB.) A. Bg.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>praerupta-monos</i> (EHRB.) A. Bg.	—	—	-2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table A (cont.)

	694	700	706	710	712	714	716	718	720	722	724	726	728	730	732	734	736	738
<i>Navicula cincta</i> (EHRB.) Kz.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>contenta</i> GRUN.	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	-3	—
<i>exelsa</i> KRASSE.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>fossalis</i> KRASSE.	-5	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>gibbula</i> CL.	—	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>gracilis</i> EHRB.	—	—	—	—	—	—	-2	—	—	—	—	—	—	—	-3	—	—	—
<i>lacustris</i> GREG.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	—	—	—
<i>longirostris</i> HUST.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	—	—	—
<i>mutica</i> Kz.	2.-	2.7	-2	—	3.9	1.2	1.1	2.6	-4	1.3	1.6	1.6	-8	4.8	2.3	2.1	3.1	3.7
<i>oblonga</i> Kz.	—	—	2.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>peregrina</i> (EHRB.) Kz.	—	—	—	—	—	.1	—	—	—	—	—	—	—	—	—	—	—	—
<i>perpusilla</i> GRUN.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>pusilla</i> W. SM.	—	—	—	—	—	—	-2	-4	-4	-4	—	-4	—	—	—	-7	-4	—
<i>pupula</i> Kz. f. <i>capitata</i> HUST.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
— f. <i>rectangularis</i> (GREG.) GRUN.	-5	—	-7	—	—	-2	—	—	—	—	—	—	—	—	—	—	—	—
<i>radiosa</i> Kz.	—	-7	-7	1.3	1.6	-3	-1	2.3	1.7	-9	-6	-4	—	1.7	2.-	-7	-7	-7
<i>subtilissima</i> CL.	—	-6	—	—	—	—	—	—	—	—	—	—	-4	-3	-3	-4	-3	—
<i>tuscula</i> (EHRB.) GRUN.	—	—	—	—	-2	-1	-1	-2	—	—	—	—	—	—	—	—	—	—
sp. (700)	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Neidium bisulcatum</i> (LOST.) CL.	-5	—	-4	-7	-2	-2	-1	-4	—	-4	-3	—	—	—	—	—	-3	—
<i>iridis</i> (EHRB.) CL.	—	—	-5	-7	-3	-2	-2	—	—	—	—	—	-4	-3	-3	—	-3	—
— var. <i>vernalis</i> REICHELT.	—	—	-2	—	-2	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>productum</i> (W. SM.) CL.	—	—	-2	—	-2	-1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Nitzschia amphibia</i> GRUN.	—	—	—	—	-2	-1	—	—	—	—	—	—	—	-2	-9	1.4	3.1	—
<i>denticula</i> GRUN.	—	—	-6	—	—	-1	-1	1.1	2.1	-8	-3	-4	-4	-5	—	—	—	—
<i>parvula</i> LEWIS.	-5	2.7	—	—	—	—	-9	—	—	—	—	—	—	—	—	—	—	—
<i>Opephora Martyii</i> HÉRIB.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Paralia sulcata</i> Kz. f. <i>radiosa</i> GRUN.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Pinnularia borealis</i> EHRB.	10.5	13.2	—	—	—	—	-2	—	—	—	—	—	.4	—	—	—	—	—
<i>Brébissonii</i> Kz. f. <i>diminuta</i> GRUN.	3.5	5.3	—	-6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>fallax</i> A. CL.	—	-7	—	—	—	—	-2	—	—	—	—	—	—	—	—	—	—	—
<i>gentilis</i> (DONK.) CL.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>interrupta</i> W. SM. f. <i>minor</i> BOYE P.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>isostauron</i> (EHRB.) GRUN.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>major</i> Kz.	—	—	—	—	—	-1	—	—	—	—	—	—	—	—	—	—	—	—
— f. <i>minuta</i> A. BG.	-5	1.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>microlauda</i> (EHRB.) A. BG.	—	—	—	—	—	—	—	—	—	-0	—	—	—	—	—	—	—	—
— f. <i>trundulata</i> A. BG.	-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

	200	150	430	150	440	880	641	536	241	237	317	258	246	356	343	289	295	134
<i>parva</i> (EHRB.) GRUN.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-4
<i>stomatophora</i> GRUN.....	—	—	—	—	-7	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>stauroptera</i> GRUN. f. <i>minuta</i> A. BG. . .	1.-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>undulata</i> GREG.....	3.-	-7	-4	—	—	-5	-1	-1	—	—	-3	—	—	-3	-3	—	—	-3
<i>viridis</i> with fae (NITZSCH) GREG.....	13.5	7.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
several indeterminate large forms...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Rhopalodia gibba</i> (EHR.) O. M.....	—	1.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.3
<i>gibberula</i> (EHR.) O. M.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>musculus</i> (Kz.) O. M.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>parallela</i> (GRUN.) O. M.....	—	—	2.5	1.3	4.1	1.5	-5	1.1	-4	.8	1.3	1.2	2.-	4.2	3.1	4.8	4.4	3.-
<i>Stauroneis legumen</i> EHRB.....	.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>phoenicenteron</i> EHRB.....	1.5	2.6	—	—	—	-1	—	—	—	—	—	—	—	—	—	—	—	—
<i>Stephanodiscus astraea</i> (EHRB.) GRUN..	-5	-7	-2	—	—	—	-3	—	—	—	—	—	—	—	-3	—	—	—
— var. <i>minutula</i> (Kz.) GRUN.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Survirella linearis</i> W. SM. var. <i>constr.</i> (EHRB.) GRUN.....	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	-2	—	—	—
indeterminable splinters.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Synedra capitata</i> EHRB.....	1.5	—	-7	-6	1.8	-9	-5	-6	1.2	-8	-6	-8	1.2	1.4	1.2	2.1	2.7	-7
<i>crystallina</i> (AG.) Kz.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	-3	—
<i>ulna</i> (NITZSCH) EHRB.....	2.-	-7	-4	—	3.-	-7	-3	-7	1.7	1.3	—	—	-8	-8	-9	2.8	3.4	-8
— var. <i>biceps</i> Kz.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Tabellaria fenestrata</i> (LYNGB.) Kz.....	4.-	8.6	—	—	—	—	—	—	—	—	—	—	—	-3	—	—	-3	—
<i>Triceratium antediluvianum</i> (EHRB.) GRUN. f. <i>pentagona</i> PERAG.....	—	—	—	—	—	—	—	—	—	—	—	—	—	-6	—	—	—	—
indeterminable.....	7.5	-6	—	-7	—	—	-2	—	—	—	—	—	—	—	—	-3	-3	3.7
Number of spec. counted																		

Table B

	740	742	744	746	749	750	760	770	780	790
<i>Achnanthes conspicua</i> A. MAYER.....	—	—	—	-.2	—	—	—	—	—	—
<i>polaris</i> ØSTR.	-.1	-.1	1.9	1.1	-.8	1.3	-.6	-.0	3.4	-.0
<i>brevipes</i> AG.	-.3	—	-.4	2.6	—	-.3	-.5	-.4	—	-.5
<i>coarctata</i> BRÉB.	—	-.1	—	-.7	—	-.0	—	—	—	—
<i>subsessilis</i> KZ.	-.1	—	—	—	—	—	—	—	—	—
<i>Actinoptychus undulatus</i> (BAIL.) RALFS.	—	—	—	—	—	—	—	-.4	-.4	-.6
<i>Amphora arenicola</i> GRUN.	—	—	—	—	-.0	-.0	3.7	-.8	-.4	—
<i>commutata</i> GRUN.	—	-.1	—	—	—	—	—	—	—	—
<i>Eunotia</i> CL.	—	—	-.0	—	—	—	—	—	—	—
<i>Grevilleana</i> GREG.	—	—	-.3	—	—	—	—	—	—	—
<i>ovalis</i> KZ.	-.3	—	—	—	—	—	—	—	—	—
— var. <i>libyca</i> (EHRB.) CL.	1.4	-.4	—	1.1	—	—	—	—	—	—
<i>proteus</i> GREG.	1.6	1.1	4.6	6.5	2.4	3.7	4.3	3.6	1.5	-.5
— var. <i>contigua</i> CL.	-.8	—	—	1.2	—	—	—	—	—	—
<i>pusilla</i> (GREG.) CL.	-.3	—	5.1	—	1.8	3.2	-.2	—	—	—
sp. I, 770.	—	—	—	—	—	—	—	-.4	—	—
sp. II, 770.	—	—	—	—	—	—	—	-.4	—	—
<i>pediculus</i> var. <i>exilis</i> GRUN.	2.7	-.9	—	—	—	—	—	—	—	—
<i>Amphiprora paludosa</i> W. SM.	—	—	—	2.1	—	—	—	—	—	—
<i>Anomoconeis sphaerophora</i> (KZ.) PFITZ-	—	—	—	—	—	—	—	—	—	—
NER.	-.3	1.4	.0	—	—	—	—	—	—	—
<i>Biddulphia aurita</i> (LYNGB.) BRÉB. & GOD.	—	—	-.6	-.4	7.8	1.7	1.2	6.4	10.7	13.1
<i>Caloneis aemula</i> (A. S.) CL.	—	—	—	—	—	—	—	—	-.4	—
<i>bacillum</i> (GRUN.) MERESCHK.	-.1	—	—	—	—	—	—	—	—	—
<i>brevis</i> GREV.	—	—	1.1	-.7	-.8	4.1	-.7	—	—	—
— f. <i>constricta</i> n. f.	—	—	—	-.2	—	—	—	—	—	—
— var. <i>distoma</i> f. <i>angustior</i> GRUN.	—	—	—	—	-.2	—	—	—	—	—
<i>formosa</i> (GREG.) CL.	—	—	-.0	2.8	-.0	—	1.1	—	—	—
<i>liber</i> var. <i>genuina</i> (W. SM.) CL.	—	—	—	—	—	2.1	-.6	-.4	—	-.6
<i>Schumanniana</i> var. <i>biconstricta</i> (GRUN.)	—	—	—	—	—	—	—	—	—	—
CL.	-.1	-.1	—	—	—	—	—	—	—	—
<i>Campylodiscus Thuretii</i> BRÉB.	—	—	-.2	—	—	—	—	-.4	—	-.0
<i>noricus</i> EHRB. var. <i>hibernica</i> (EHRB.)	—	—	—	—	—	—	—	—	—	—
GRUN.	-.8	-.7	—	—	—	—	—	—	—	—
<i>Chaetoceros ceratosporum</i> ØSTF.	—	—	—	.2	—	—	—	—	—	—
<i>groenlandicus</i> CL.?	—	—	—	.2	—	—	—	—	—	—
<i>paradoxum</i> PER.?	—	—	-.2	—	—	—	—	—	—	—
<i>Wighamii</i> BRIGHTW.1	1.1	—	—	—	—	—	—	—	—
sp.	—	—	—	-.3	—	—	—	—	—	—
<i>Cocconeis costata</i> GREG.	—	—	—	-.7	-.0	-.0	-.0	2.7	-.8	1.6
— var. <i>Baldjickiana</i> GRUN.	—	—	—	—	-.4	-.0	-.7	1.2	—	—
— var. <i>pacifica</i> GRUN.	—	—	—	—	—	-.0	-.0	-.8	—	—
<i>pediculus</i> EHRB.	8.2	6.3	-.0	—	-.0	—	—	—	—	—
<i>pelta</i> A. S.	—	—	—	—	—	—	—	—	-.0	—
sp.	-.8	-.7	-.4	—	—	-.0	-.0	-.8	-.4	1.1
<i>scutellum</i> var. <i>stauroneiformis</i> EHRB.	-.4	-.5	-.5	1.4	3.9	-.4	-.7	7.6	4.2	2.2
<i>Coscinodiscus anguste-lineatus</i> A. S.	—	—	—	—	—	—	—	2.7	1.5	—
<i>bathyomphalus</i> CL.	—	-.1	—	-.3	—	-.0	—	-.4	—	—
<i>curvatulus</i> GRUN.1	-.1	-.7	.2	—	-.4	—	—	—	1.7
— var. <i>minor</i> (EHRB.) GRUN.	—	—	-.9	—	-.0	1.2	—	—	—	—
<i>decipiens</i> GRUN.	—	—	—	—	-.3	-.2	1.2	4.7	3.8	1.1
<i>decrescens</i> var. <i>polaris</i> ? GRUN.	—	—	—	-.2	—	—	—	—	—	—
<i>excentricus</i> EHRB.	—	—	1.6	—	—	-.0	-.4	—	—	-.5
<i>Hauckii</i> GRUN.	—	—	—	—	—	—	—	-.0	—	—
<i>lacustris</i> GRUN.	-.3	-.5	—	-.2	—	—	—	—	—	—

Table B (cont.)

	740	742	744	746	749	750	760	770	780	790
<i>Coscinodiscus lacustris</i> var. <i>septentrionalis</i> GRUN.....	—	.7								
<i>oculus iridis</i> EHRB.....	-.3	-.7	—	-.3	-.8	-.0	-.8	-.8	-.7	3.3
<i>radiatus</i> EHRB.....	—	-.2	—	—	-.3	-.7	-.6	—	-.4	3.8
— var. <i>borealis</i> (EHRB.) GRUN.....	—	—	—	—	—	-.1				
<i>Rothii</i> (EHRB.) GRUN. var. <i>subsalsa</i> I. DFT.?	—	—	—	—	—		.1	-.4		
<i>sublineatus</i> GRUN.....	—	—	—	—	—	-.2				
<i>subtilis</i> EHRB. var. <i>glacialis</i> GRUN.?	—	—	—	-.2						
sp. 740.....	-.1									
<i>Cyclotella antiqua</i> W. SM.....	-.7	1.1								
<i>Kützingiana</i> THWAITES.....	—	-.4								
<i>Cymatopleura solea</i> (BRÉB.) W. SM.....	-.1									
<i>Cymbella aspera</i> (EHRB.) CL.....	-.4									
<i>cistula</i> (HEMPR.) GRUN.....	-.4	-.4								
sp.....	—	—								
<i>cymbiformis</i> (AG.) V. H.....	2.1	1.5			.0					
<i>Ehrenbergii</i> Kz.....	2.-									
— f.a.....	1.7									
<i>helvetica</i> Kz. f.a.....	-.6	1.6								
<i>lanceolata</i> (EHRB.) V. H.....	-.3	-.4								
<i>pusilla</i> GRUN.....	—	—	-.4	—		-.0				
<i>ventricosa</i> Kz.....	-.5	-.4								
<i>Reinhardtii</i> GRUN.....	-.6	-.7	—	-.2						
<i>Denticula elegans</i> Kz.....	3.2	1.3								
<i>Dimerogramma minor</i> GREG.....	—	-.1	2.1	-.4	-.0	2.1	1.3	-.4		
<i>lanceolatum</i> PER.....	—	-.0								
<i>Diploneis chersonensis</i> GRUN.....	—	—	—	—	—	-.0	—	1.6		
<i>didyma</i> EHRB.....	2.1	-.1	11.8	2.3	1.3	6.2	1.1	2.4	-.7	4.9
<i>fusca</i> GREG.....	—	-.1	-.3	-.7	43.5	37.4	35.8	26.2	2.7	1.7
— var. <i>aestiva</i> (DONK.) CL.....	—	—	—	-.2						
— var. <i>hyperborea</i> GRUN.....	—	—	—	-.2						
<i>incurvata</i> GREG.....	—	-.3	—	-.3						
<i>interrupta</i> Kz.....	-.1	-.1	1.6	-.9	—	-.1				
<i>litoralis</i> DONK.....	—	—	-.5	—	-.3	2.8	—	—	—	1.1
<i>notabilis</i> GREV. f. <i>expleta</i> A. S.....	—	—	—	-.2						
<i>oculata</i> BRÉB.....	—	-.1								
<i>ovalis</i> HILSE.....	-.4	-.3								
<i>pseudovalis</i> HUST.....	—	—	—	-.2						
<i>Smithii</i> (BRÉB.) CL.....	—	—	-.9	—	2.6	-.2	—	12.1		
<i>Epithemia argus</i> Kz. & var. <i>intermedia</i> FRICKE.....	-.9	1.1								
<i>sorex</i> Kz.....	3.2	2.7								
<i>turgida</i> (EHRB.) Kz. & var. <i>granulata</i> (EHRB.) GRUN.....	4.4	3.9								
<i>zebra</i> (EHRB.) Kz.....	1.5	1.4	-.0		—	—	-.6			
<i>Fragilaria brevistriata</i> GRUN.....	1.6									
<i>capucina</i> DESMAZ.....	-.1									
<i>construens</i> (EHRB.) GRUN.....	-.8									
— var. <i>binodis</i> (EHRB.) GRUN.....	-.5									
— var. <i>subsalina</i> HUST.....	12.4	3.9								
<i>intermedia</i> GRUN.....	-.1									
<i>nitzschoides</i> GRUN.....	-.3									
<i>pinnata</i> EHRB.....	-.7	-.9								
<i>Vaucheriae</i> Kz.....	-.3									
<i>virescens</i> RALFS.....	-.4									
<i>Gomphonema acuminatum</i> EHRB.....	1.1									

Table B (cont.)

	740	742	744	746	749	750	760	770	780	790
<i>Gomphonema acuminatum</i> var. <i>coronatum</i> (EHRB.) W. SM.	-9	-5								
— var. <i>Brebissonii</i> (Kz.) CL.	-4									
<i>angustatum</i> (Kz.) RBH.	-3	-1								
<i>augur</i> EHRB.	-7									
<i>constrictum</i> EHRB.	1.7	-8	—	—	—	-0				
<i>geminatum</i> LYNGBYE	—	—	—	—	—	—	—	—	-3	
<i>gracile</i> EHRB.	-1									
<i>intricatum</i> Kz.	-5	-5								
— var. <i>pumila</i> GRUN.	1.6	1.1								
<i>parvulum</i> Kz.	-1									
— var. <i>subelliptica</i> CL.	-1									
<i>Grammatophora arcuata</i> EHRB.	-1	-1	—	-7	—	2.6	—	—	—	-0
<i>angulosa</i> EHRB.	—	—	1-	—	—	1-	1.8	1.2	—	-0
— var. <i>islandica</i> (EHRB.) GRUN.	—	—	-4	—	-5	-2	—	2-	3.8	1.1
<i>maxima</i> GRUN.	—	—	—	—	—	—	—	—	-3	
<i>marina</i> (LYNGB.) Kz.	—	—	—	-2	—	-0				
<i>oceanica</i> (EHRB.) GRUN. var. <i>macilenta</i> (W. SM.) GRUN.	—	—	1.1	-5	2.9	-4	—	4.8	11.4	2.2
<i>Gyrosigma acuminatum</i> Kz.	—	2.8								
<i>attenuatum</i> (Kz.) CL.	1.5	-1	-0							
<i>fasciola</i> (EHRB.) CL.	—	—	—	—	-4	—	—	-4		
<i>Hantzschia amphioxys</i> (EHRB.) GRUN.	—	-2								
<i>marina</i> (DONK.) GRUN.	—	—	-4	2.3	-0	1.6	1.7			
<i>virgata</i> (ROPER) GRUN.	—	—	—	-2						
<i>Hyalodiscus scoticus</i> (Kz.) GRUN.	—	.7	-3	-5	-6	-1	—	-4	9.5	1.6
<i>stelliger</i> BAIL.	—	—	—	-2	—	-0	1.2			
<i>Mastogloia Braunii</i> GRUN.	-5	1.6								
<i>coarctata</i> n. sp.	1.1									
<i>exigua</i> Lewis.	—	—	—	—	—	-0	—	-8	-4	
<i>exigua</i> Lewis var. <i>rostellata</i> A. CL.-E.?	—	—	—	-2						
<i>pusilla</i> GRUN.	—	—	—	-2						
<i>Smithii</i> THWAITES.	1.7	-5								
— var. <i>amphicephala</i> GRUN.	-1	-4								
— var. <i>lacustris</i> GRUN.	-1									
<i>streptoraphe</i> n. sp.	-1									
<i>Melosira lineata</i> AG.	—	—	—	—	-4	—	—	-4	—	1.1
<i>islandica</i> subsp. <i>helvetica</i> O. M.	—	—	—	—	-3	-0				
<i>italica</i> (EHRB.) Kz.	—	—	—	—	-0	-0	—	-0	-7	
— var. <i>subarctica</i> O. M.	—	—	—	-3						
<i>varians</i> AG.	—	-2								
<i>Meridion circulare</i> AG.	-1									
<i>Navicula abrupta</i> (GREG.) CL.	—	—	-0	-9	—	-0	1.2	—	-4	-5
<i>bacillum</i> EHRB.	-5									
<i>granulata</i> BRÉB.	—	—	-5							
<i>cancellata</i> DONK.	—	—	-5	-3	-2					
<i>cari</i> EHRB.	-1	-2								
— var. <i>angusta</i> GRUN.	-1									
<i>cincta</i> (EHRB.) Kz.	—	-1								
<i>cryptocephala</i> Kz.	—	-2								
— var. <i>veneta</i> (Kz.) GRUN.	—	-4	—	-8						
<i>digitoradiata</i> (GREG.) A. S.	-4	-5	3.5	-9	1-	1.3	3.1	-0		
<i>directa</i> var. <i>genuina</i> (W. SM.) CL., CL.	—	—	—	—	—	—	-5	-4		
<i>distans</i> (W. SM.) CL.	—	—	—	—	—	—	—	—	—	3.3
<i>elegans</i> W. SM.	—	-2								
<i>excelsa</i> KRASSKE.	-5									

Table B (cont.)

	740	742	744	746	749	750	760	770	780	790
<i>Navicula forcipata</i> GREV. var. <i>densestr.</i>										
& f. <i>minuta</i> A. S.	—	—	—	3.						
<i>gracilis</i> EHRB.	—	1.1								
<i>Grevillei</i> DONK.	—	—	—	—	—	—	—	—	—	—
<i>Hennedyii</i> W. SM.	—	—	—	—	—	—	—	—	—	—
— var. <i>minuta</i> CL.	—	—	—	—	—	—	—	—	—	—
<i>humerosa</i> BREB.	—	—	—	—	—	—	—	—	—	—
<i>hungarica</i> GRUN. var. <i>capitata</i> (EHRB.)										
CL.	—	—	—	—	—	—	—	—	—	—
<i>hyalina</i> DONK.	—	—	—	—	—	—	—	—	—	—
<i>lacustris</i> GREG.	—	—	—	—	—	—	—	—	—	—
<i>libellus</i> GREG. var.	—	—	—	—	—	—	—	—	—	—
<i>peregrina</i> (EHRB.) KZ. var. <i>Meniscus</i>										
SCHUM.	—	—	—	—	—	—	—	—	—	—
<i>oblonga</i> KZ.	3.1	2.—	—	—	—	—	—	—	—	—
<i>palpebralis</i> BREB. var. <i>minor</i> GRUN. ...	—	—	—	—	—	—	—	—	—	—
— var. <i>semiterna</i> CL.	—	—	—	—	—	—	—	—	—	—
<i>placentula</i> (EHRB.) GRUN. f. <i>rostrata</i>										
A. MAYER.	—	—	—	—	—	—	—	—	—	—
<i>praecepta</i> n. nom.	—	—	—	—	—	—	—	—	—	—
<i>punctulata</i> W. SM.	—	—	—	—	—	—	—	—	—	—
<i>pupula</i> KZ. f. <i>rectangularis</i> (GREG.)										
GRUN.	—	—	—	—	—	—	—	—	—	—
<i>radiosa</i> KZ.	—	—	—	—	—	—	—	—	—	—
<i>Reinhardtii</i> GRUN.	—	—	—	—	—	—	—	—	—	—
<i>rhynchocephala</i> KZ. var. <i>amphiceros</i> KZ.										
<i>solida</i> CL.	—	—	—	—	—	—	—	—	—	—
<i>subimpressa</i> CL.?	—	—	—	—	—	—	—	—	—	—
<i>tuscula</i> (EHRB.) GRUN.	—	—	—	—	—	—	—	—	—	—
<i>torneensis</i> CL. var.?	—	—	—	—	—	—	—	—	—	—
sp. 746.	—	—	—	—	—	—	—	—	—	—
sp. 770.	—	—	—	—	—	—	—	—	—	—
<i>Neidium productum</i> (W. SM.) CL.	—	—	—	—	—	—	—	—	—	—
<i>Nitzschia acuminata</i> (W. SM.) GRUN.	—	—	—	—	—	—	—	—	—	—
<i>amphibia</i> GRUN.	—	—	—	—	—	—	—	—	—	—
<i>bilobata</i> W. SM.	—	—	—	—	—	—	—	—	—	—
<i>commutata</i> GRUN.	—	—	—	—	—	—	—	—	—	—
<i>constricta</i> (GREG.) GRUN. var. <i>parva</i>										
V. H.	—	—	—	—	—	—	—	—	—	—
<i>dissipata</i> (KZ.) GRUN.	—	—	—	—	—	—	—	—	—	—
<i>gracilis</i> HANTZSCH.	—	—	—	—	—	—	—	—	—	—
<i>hungarica</i> GRUN.	—	—	—	—	—	—	—	—	—	—
<i>hybrida</i> GRUN. var. <i>pellucida</i> GRUN. ...	—	—	—	—	—	—	—	—	—	—
<i>incurva</i> GRUN.	—	—	—	—	—	—	—	—	—	—
<i>punctata</i> (W. SM.) GRUN.	—	—	—	—	—	—	—	—	—	—
<i>sigma</i> (KZ.) W. SM.	—	—	—	—	—	—	—	—	—	—
<i>sigmoidea</i> (EHRB.) W. SM.	—	—	—	—	—	—	—	—	—	—
<i>socialis</i> GREG.	—	—	—	—	—	—	—	—	—	—
<i>spectabilis</i> (EHRB.) RALFS.	—	—	—	—	—	—	—	—	—	—
<i>subtilis</i> KZ.	—	—	—	—	—	—	—	—	—	—
<i>tryblionella</i> HANTZSCH var. <i>debilis</i> (AR-										
NOTT) A. MAYER.	—	—	—	—	—	—	—	—	—	—
<i>vermicularis</i> (KZ.) GRUN.	—	—	—	—	—	—	—	—	—	—
<i>vitrea</i> NORMAN var. <i>salinarum</i> GRUN. ...	—	—	—	—	—	—	—	—	—	—
<i>insignis</i> W. SM. var. <i>arctica</i> GRUN.? ...	—	—	—	—	—	—	—	—	—	—
<i>Oestrupia blanda</i> A. S.	—	—	—	—	—	—	—	—	—	—

Table B (cont.)

	740	742	744	746	749	750	760	770	780	790
<i>Opephora marina</i> PETIT.....	-4									
<i>Paralia sulcata</i> Kz. f. <i>radiosa</i> GRUN...	-9	3.2	28.5	-5	—	-5	—	—	-7	1.7
— f. <i>coronata</i> GRUN.....	—	1.5								
— var. <i>biseriata</i> GRUN.....	—	—	.0	—	—	-0	-6	—	2.3	4.9
<i>Pinnularia lata</i> (BRÉB.) W. SM.....	—	—								
<i>microclauda</i> (EHRB.) Å. BG.....	-1								-0	
<i>neglecta</i> (A. MAYER) Å. BG.....	-1									
<i>quadratarea</i> A. S.....	—	—	-2	3.9	7.3	1.6	4.9	1.2	-0	-0
<i>stauroptera</i> GRUN. f. <i>minuta</i> Å. BG.....	—	—	-0							
<i>viridis</i> with fæe (NITZSCH) EHRB....	—	-1								
<i>Plagiogramma staurophorum</i> (GREG.) HEIB.....	—	—	-1	-2	-1	-4	1.2	—	4.2	4.9
<i>Pleurosigma elongatum</i> W. SM.....	—	—	—	-2	—	-6	3.1			
<i>Podosira maxima</i> (Kz.) GRUN.....	—	-1	—	-2	.0					
<i>Rhabdonema arcuatum</i> (LYNGB.? AG.) Kz.	—	—	1.7	-5	2.3	1.7	-6	2.4	17.2	25.8
<i>minutum</i> Kz.....	—	—	-2	-3	-3	-6	-0	1.2	12.5	5.5
— f. <i>capitata</i> n. f.....	—	—	—	—	—	—	—	-0		
var. <i>sulcata</i> FRICKE.....	—	—	-0							
<i>Rhoicosphenia marina</i> (W. SM.) M. SCHMIDT?.....	-1	-5	—	-3	—	.0	—	—	-4	
<i>Rhopalodia gibba</i> (EHRB.) O. M.....	1.2	2.5								
<i>musculus</i> (Kz.) O. M.....	-1	-9	-5	1.1	—	-5	—	—	—	-4
<i>parallela</i> (GRUN.) O. M.....	-8	-5								
<i>Sceptroneis marina</i> (GREG.) V. H.....	—	—	—	—	—	—	—	—	-0	-0
<i>Scoliopleura tumida</i> (BRÉB.) RBH.....	-3	-8	7.7	12.4	-0	2.1	3.1	-4		
— var. <i>cruciata</i> n. var.....	—	-5	—	3.7						
<i>Scoliotropis latestriata</i> BRÉB.....	—	—	—	-7						
<i>Stauroneis Gregorii</i> RALFS.....	—	-1	-5	-5	—	-3	-6			
<i>salina</i> W. SM.....	—	—	-0	1.9						
sp. 746.....	—	—	—	-2						
<i>Stephanodiscus astraea</i> (EHRB.) GRUN...	—	—	—	—	-2					
— var.?.....	—	—	—	—	—	—	—	-4		
<i>Stephanopyxis</i> sp.....	—	—	-0	—	—	-0				
<i>Striatella delicatula</i> (Kz.) GRUN.....	—	—	-0							
<i>groenlandica</i> ÖSTR.?.....	—	—	—	—	—	—	—	—	—	-0
<i>Surirella comis</i> A. S.....	—	—	—	-2						
<i>gemma</i> EHRB.....	—	—	—	—	-3	—	—	-4		
<i>fastuosa</i> EHRB.....	—	—	-0	—	—	-0	-5	—	—	-5
<i>striatula</i> TURPIN.....	.1	1.4	—	-2						
<i>Synedra affinis</i> Kz.....	—	1.1	-5	-5	5.7	-0	-7	-8	-5	3.8
— var. <i>parva</i> (Kz.) GRUN.....	—	—	—	—	-4					
<i>capitata</i> EHRB.....	2.5	2.5		—						
<i>crystallina</i> (AG.) Kz.....	—	1.9	2.3	1.1	-2					
<i>pulchella</i> Kz.....	-1	-1								
<i>Trachyneis aspera</i> (EHRB.) CL.....	-1	—	—	-2	-3	-0	—	-4	1.9	3.3
<i>Triceratium antediluvianum</i> (EHRB.) GRUN. f. <i>pentagona</i> PERAG.....	-8	5.5	-3	—	-3					
<i>Tropidoneis maxima</i> (GREG.) CL.....	—	—	—	2.5						
<i>Thalassiothrix Frauenfeldii</i> GRUN.....	—	—	—	-3						
Number of valves counted	754	854	532	567	385	419	162	249	264	183
Total sum of valves counted	10 512									

Explanation of plates

Plate I

- Achnanthes* I: *Biasolettiana*, *conspicua*.
Cyclotella I: *comta* v. *radiosa*, *Kutzingiana* v. *planetophora*, *Meneghiniana*, *ocellata*, *striata*.
Cymbella I: *cistula*, *cymbiformis*, *helvetica* f: a, *ventricosa*.
Cymbella II: *aequalis*, *affinis*, *aspera*, *caesatii*, *caespitosa*, *cistula* f: a, *cuspidata*, *laevis*, *parva*, *prostrata*, *tumida*.
Cymbella III: *gracilis*, *incerta*, *naviculiformis*.
Eunotia I: *alpestris*, *bactriana*, *denticulata*, *exigua-gracilis*, *Grunowii* var. *dispersa*, *lapponica*, *major*, *monodon*, *pectinalis* & f. *minor*, *polyglyphis*, *praerupta-minor* & -*monos*, *sudetica*, *tenella*, *lunaris*, sp.
Gomphonema I: *acuminat.* & v. *Brebissonii*, *constrictum*, *lanceolatum*, *subclavatum*, *subtile*, *tergestinum*, *vibrio*.
Gomphonema IV: *intricatum* & v. *pumila* and *fossilis*, *parvulum*.
Navicula I: *abrupta*, *granulata*, *cancellata*, *directa* v. *genuina*, *distans*, *forcipata* v. *densestriata* with f. *minuta*, *Grevillei*, *Hennedyi* & v. *minuta*, *humerosa*, *hyalina*, *libellus* var., *peregrina*, v. *Meniscus*, *palpebralis* v. *minor* and v. *semiterna*, *punctulata*, *solida*, spp.
Navicula II: *cryptocephala* & v. *intermedia* & *veneta*, *digitoradiata*, *elegans*, *hungarica* v. *capitata*, *placentula* f. *rostrata*, *rhynchoc.* v. *amphic.*, *peregrina*, *salinarum*, sp.
Navicula III: *bacillum*, *cari* & v. *angusta*, *cincta*, *excelsa*, *gracilis*, *lacustris*.
Navicula IV: *pusilla*, *pupula* & f: ae, *radiosa*, *tuscula*.
Navicula V: *contenta*, *fossalis*, *gibbula*, *mutica*, *subtilissima*, sp.
Neidium I: *bisulcatum*, *iridis* & v. *vernalis*, *productum*.
Pinnularia I: *gentilis*, *lata*, *major*, *microclauda*, *neglecta*, *nobilis*, *parva*, *stomatophora*, *stauroptera* f. *parva*.
Pinnularia II: *borealis*. *Brebi* f. *diminuta*, *fallax*, *interrupta* f. *minor*, *isostauron*, *major* f. *minuta*, *microcl.* f. *triundulata*, *pachycephala*, *undulata*, *viridis* & f: ae.

Plate II

1. *Cyclotella antiqua* W. SM.
2. *Achnanthes polaris* OESTR.
3. *Amphora ovalis* Kz. var. *libyca* (EHRB.) CL.
4. — sp. I.
5. — sp. II.
6. *Caloneis formosa* (GREV.) var. *holmiensis* CL.?
7. — *brevis* GREG. f. *constricta* n. f.
8. *Cocconeis* sp.
9. *Chaetoceros paradoxum* PER.?
10. — *groenlandicus* CL.?
11. *Cymbella* sp.
12. *Coscinodiscus bathyomphalus* CL.
13. *Dimerogramma lanceolatum* PER.
14. *Eunotia* sp.
15. *Mastogloia coarctata* n. sp.
16. — *exigua* LEWIS var. *rostellata* A. CL.-E.?
17. — *streptoraphe* n. sp.
18. *Navicula praecepta* n. nom.
19. — *subimpressa* GRUN.?
20. — *tuscula* (EHRB.) GRUN. var.?
21. — *torneensis* CL. var.?
22. — sp.
23. *Nitzschia insignis* W. SM. var. *arctica* GRUN.?
24. *Rhabdonema minutum* Kz. f. *capitata* n. f.
25. — — var. *sulcata* FRICKE.

26. *Rhoicosphenia marina* (W. SM.) M. SCHMIDT var.?
27. *Sceptroneis marina* GREG.
28. *Scoliopleura tumida* (BREB.) RBH. var. *cruciata* n. var.
29. *Stauroneis* sp.
30. *Striatella groenlandica* ÖSTR. var.?
31. *Coscinodiscus Hauckii* GRUN.?

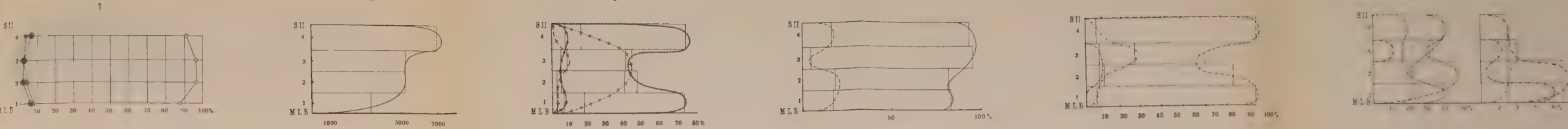
Plate III

1. *Diploneis* sp. (cfr *D. fusca*) (GREG.) CL. v. *aestiva* DONK.
2. *Gomphonema vibrio* (EHRB.) CL.
3. *Surirella Comis* A. S.
4. *Campylodiscus Thuretii* BREB.
5. *Mastogloia (Smithii)* THWAITES f.a.?
6. *Rhabdonema minutum* Kz. f. *monstr.* (cfr A. S. Atl. T. 220: 11).
7. *Hemiaulus polymorphus* GRUN. v. *frigida* GRUN.
8. *Pyxidicula liasica* ROTHPL.
9. *Cocconeis placentula* EHRB. "f. *klinoraphis* GEITL."
10. — *costata* GREG. var. *pacifica* (GRUN.) CL.
11. *Caloneis Schumanniana* (GRUN.) CL. var. *biconstricta* GRUN. f.a.
12. — sp. cfr *alpestris* (GRUN.) CL. see also HUST. 1935 fig. 1:10 a.
13. — sp. — 90×21 ; str. 18. Besides the narrow fenster-band one inframarginal baulk.
14. *Cymbella Ehrenbergii* f.a.
15. — sp. Cfr *C. parva* (W. SM.) CL. Dim. 107×20 ; str. 6. coarsely punctuate in quincunx.
16. — sp. Cfr *C. cistula* (HEMPR.) GRUN. — Str. 6, lin. $8/10 \mu$.
17. *Scoliopleura (Tumida?)*, with a most conspicuous fenster-band.
18. *Paralia sulcata* EHRB. f. *radiata* GRUN.
19. *Cyclotella antiqua* W. SM.
20. — *Kutzingiana* THWAITES.
21. — *ocellata* PANT.
- 22, 23. — *comta* (EHRB.) Kz.
24. Unknown form.

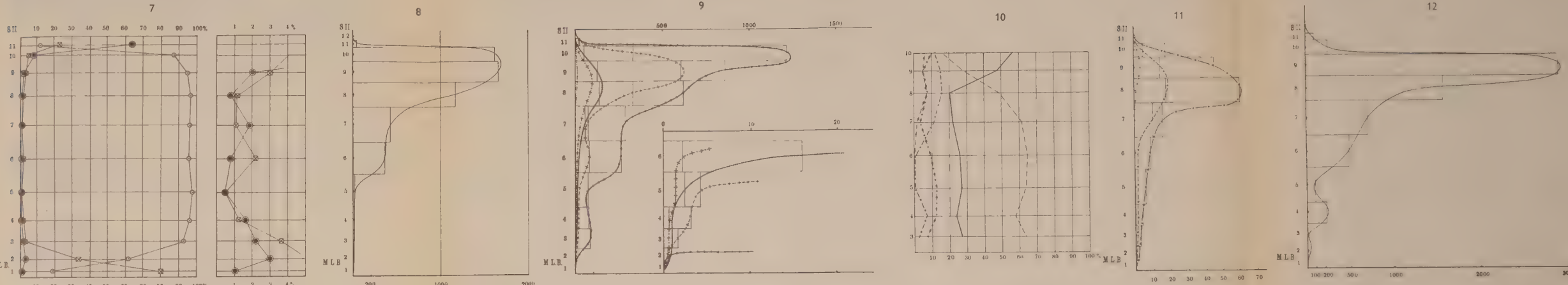
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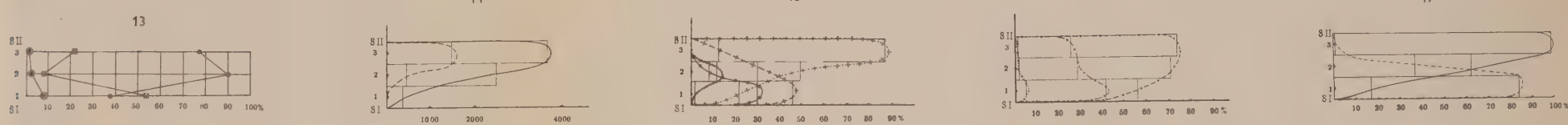
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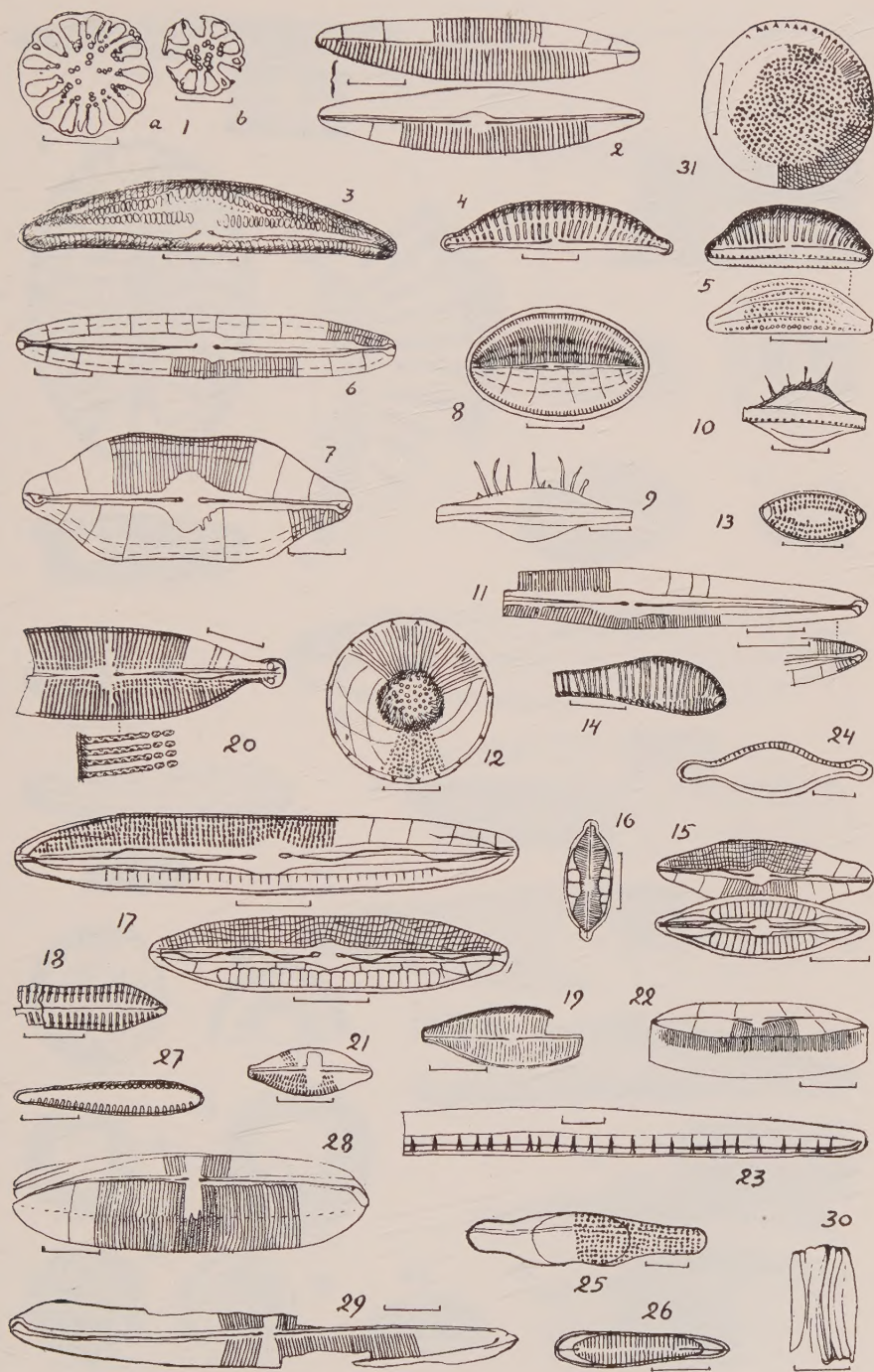
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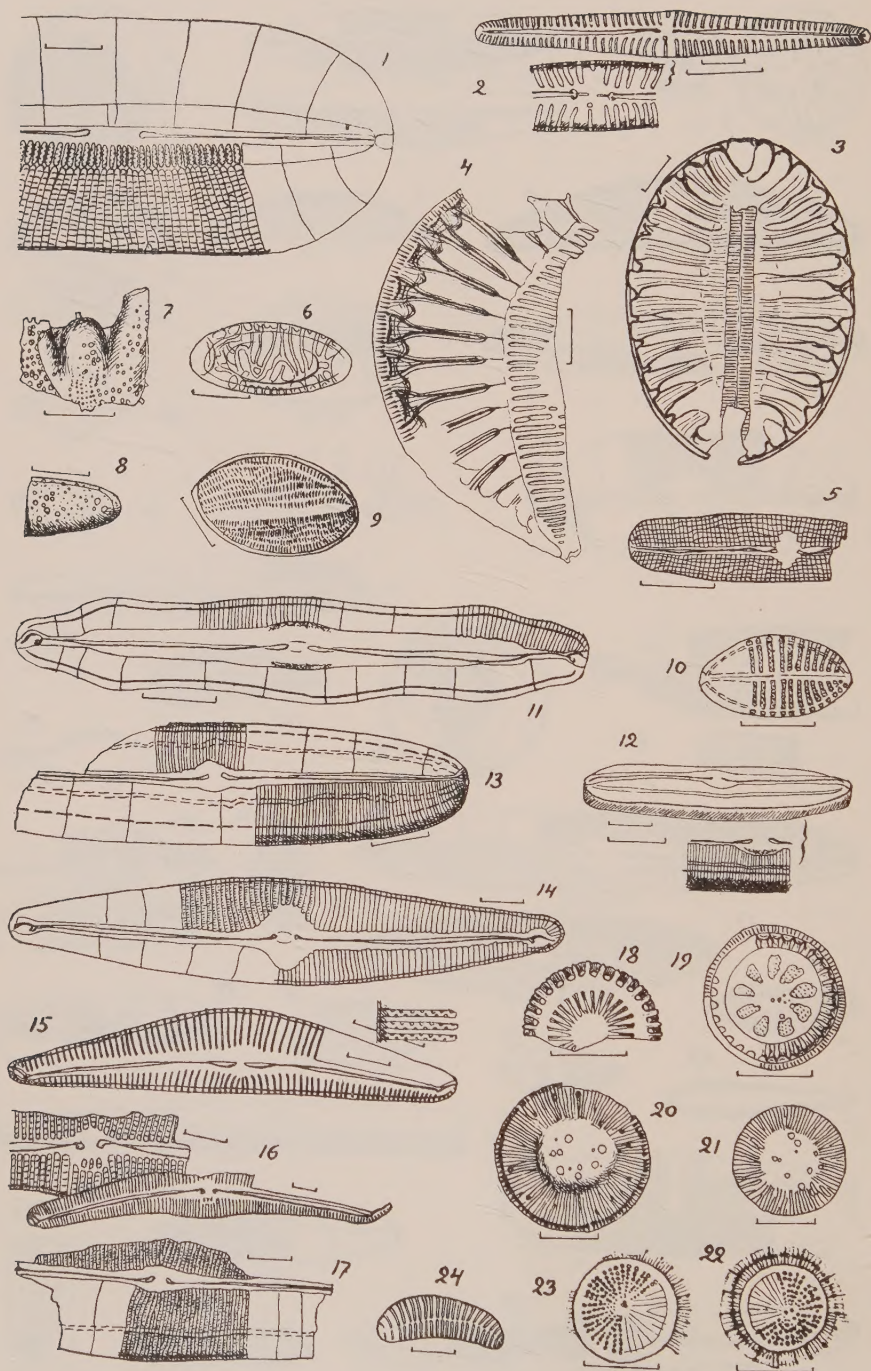


Fossane:



- Symbols
- Minerogene components
 - Organogene
 - Calcareous
 - Sphaerulæ
 - Lymnaeidae
 - Planorbidae
 - Valvatidae
 - Physidae
 - Ancylidae
 - Gyraulus arcticus*
 - Hippesulus complanatus*
 - Armiger crista*
 - Pygidium nitidum*
 - P. milium*
 - P. obtusale*
 - P. subtruncatum*
 - P. liljeborgi*
 - P. hibernicum*
 - P. henningsianum*





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